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SKETCHES OF ENGINE AND MACHINE DETAILS.

WALLACE BENTLEY, M.I.M.E.

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SKETCHES OF ENGINE

— AND —

MACHINE DETAILS.

A Reference Book for the use of Engineers, Draughtsmen, and Mechanics, and a Text Book for Machine Construction and Drawing Classes.

BY

WALLACE BENTLEY, M.I.Mech.E.,

Consulting Mechanical Engineer, Halifax.

AUTHOR OF

"Machine Shop Companion." "Questions in Machine Construction."
"Questions in Applied Mechanics." "Rules and Definitions,"
and "Practical Workshop Mechanics."

SIXTH EDITION.

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CONTENTS.

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		Pages.
(1)	General Instructions on Preparing Drawings, etc...	1 to 9
(2)	Rivets and Riveted Joints	10 ,, 16
(3)	Bolts, Nuts and Screws	17 ,, 20
(4)	Keys, Cotters and Pins	21 ,, 24
(5)	Pipes and Pipe Joints	25 ,, 26
(6)	Shafting, Couplings and Clutches	27 ,, 30
(7)	Bearings, Pedestals, Hangers, etc....	31 ,, 38
(8)	Pulleys and Flywheels	39 ,, 42
(9)	Toothed Gearing	43 ,, 46
(10)	Engine Details	47 ,, 73
(11)	Valves...	74 ,, 83
(12)	Machine Tool Details	84 ,, 98
(13)	Electric Dynamo and Motor Details	99 ,, 105
(14)	Steam Boilers and Details	106 ,, 109
(15)	Hydraulic Details	110 ,, 111
(16)	Miscellaneous Details	112 ,, 118
(17)	Notes on Materials, Weight Estimating and Stresses	119 ,, 121

For Complete Index, see Pages 123, 124 and 126.

PREFACE.

IN consequence of the great success attained by my previous engineering publications, and at the request of a large number of Engineers, Technical School Teachers, Students, and Mechanics, in all parts of the United Kingdom, I have pleasure in issuing this book of "Sketches of Engine and Machine Details," and trust that it will prove as successful as my other works.

Sketching plays such an important part in all engineering examinations, as well as in the everyday occupations of the engineer and draughtsman, that it is of the greatest importance that students and apprentices should be trained to answer practical questions by means of neat and proportionate sketches. One of the objects of this book is to supply suitable examples, fully worked out, showing students exactly the kind of thing required, and another is to give dimensioned details of the most recent practice in the shops.

With the wealth of material at my disposal, some difficulty has been experienced in selecting what was most suitable for the purpose of the work, but I hope that this may have been so managed, as to furnish a book valuable not only to the student, but to all interested in Mechanical Science.

I wish to express my best thanks to the eminent engineers and engineering firms (whose names appear in the body of the work) for kindly supplying me with working detail drawings of their most recent practice, and to Professor Unwin, Professor Adams, Messrs. Cryer and Jordan, and Messrs. Low and Bevis, for a few sketches taken from their works.

W.B.

CROSSLEY STREET,
HALIFAX,
March, 1898.

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PREFACE
TO THE FIFTH EDITION.

IN preparing this new edition, the opportunity has again been taken of giving the work a thorough revision. Nearly thirty pages of new drawings have been added and much descriptive matter. A few of the older drawings have been discarded and more up-to-date designs substituted, whilst many of the standard details have been re-drawn.

The former practice of dividing the book into two parts, viz:—Elementary and Advanced has now been abandoned, and the subject matter is arranged together in sections, as shown by the Contents page. This feature will, I trust, make the book more handy for reference.

My sincerest thanks are due to the eminent engineers and firms who have so kindly supplied me with working drawings; to my son, Mr. Hubert Bentley, G. I. Mech. E., who has undertaken much responsibility in connection with the work, and to my junior draughtsman, Mr. Horace Horsfall, for the preparation of some of the drawings.

Finally, I take this opportunity to thank the large number of Engineers, Draughtsmen, Technical School Teachers and others, in all parts of the world, who have written to me expressing their kind appreciations of the work.

W.B.

PREFACE
TO THE SIXTH EDITION.

THE Fifth edition having been thoroughly revised, it has not been found necessary to make any change in the present issue.

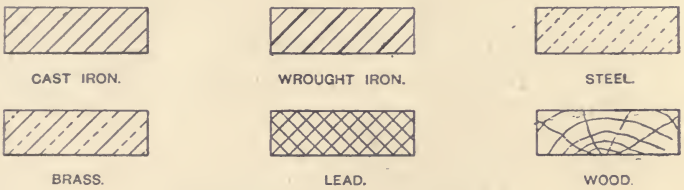
W.B.

HALIFAX, 1916.

GENERAL INSTRUCTIONS.—*(see preface).*

1. The numbers enclosed in Brackets, thus (26) represent the number of the question in the Author's Book "Questions in Machine Construction."

2. The Materials employed in the construction of the various details illustrated in this Book are indicated by the following section lines.



3. The Examples may be drawn to any convenient scale at the discretion of the teacher or student, a large number may be drawn full size, others to scale, half size, quarter size, etc., extra views must be added as asked for in order to show that the exact form or shape of each detail is realized. *This is a very important requirement and should receive careful attention from the beginning.*

4. In some of the Examples a few minor dimensions have been purposely omitted in order to test the ability of the student to design and proportion such parts.

5. A single accent (′) signifies feet, a double accent (″) inches, thus 2′ 6″ means that the dimension is 2 feet 6 inches.

6. Where proportions are given such as in the case of the Pedestal on page 31, it will be good practice for a student to take a common size of shaft, say from 1½″ to 4″ dia. and design a Pedestal to suit.

7. In answering the questions herein asked it is as a rule unnecessary to insert any but the leading dimensions, these are added in the book to enhance the value of the sketches and to provide examples suitable for drawing to scale.

NOTE.—Questions marked with an asterisk (*) are taken from the Board of Education Examination Papers, by permission of the Controller of His Majesty's Stationery Office.

NOTES ON DRAWING TO SCALE.

In preparing drawings of Machines it is usual to make:

(1) "*General arrangement drawings*" of the complete machine.
(2) "*Working or detail drawings*" of the separate parts.

These are "drawn to scale." For example, in the drawing of a large machine or engine it will readily be seen that it is impossible to draw it full size, it is therefore reduced proportionately or as it is called "*drawn to scale*," *e.g.* suppose it is reduced to one-eighth full size, then every $1\frac{1}{2}$ inches measured on the drawing will represent one foot in the machine, or the scale of the drawing will be $1\frac{1}{2}'' = 1$ foot.

The scales most generally adopted in engineering practice are,
For general arrangement drawings:—$\frac{1}{2}''$, $\frac{3}{4}''$, $1''$, $1\frac{1}{2}''$, $2''$, and $3''$ to the foot.
For working or detail drawings:—$3''$, $4\frac{1}{2}''$, and $6''$ to the foot.

All small parts should be drawn full-size.

It is *very important* that the scale should be put prominently on every drawing.

See Examples of Scales on page 7.

PRINCIPLES OF PROJECTION.

The chief purpose in Machine Drawing is to enable the designer or draughtsman to convey his ideas to the workman, so that the mechanism or machine can be constructed. It is therefore necessary for the drawing to give the exact size and form of the machine and its several parts. For this purpose Orthographic Projection is used. An example of this is shown in the accompanying sketch, Fig. 1, where the principle of projection is applied to the drawing of a cast iron beam.

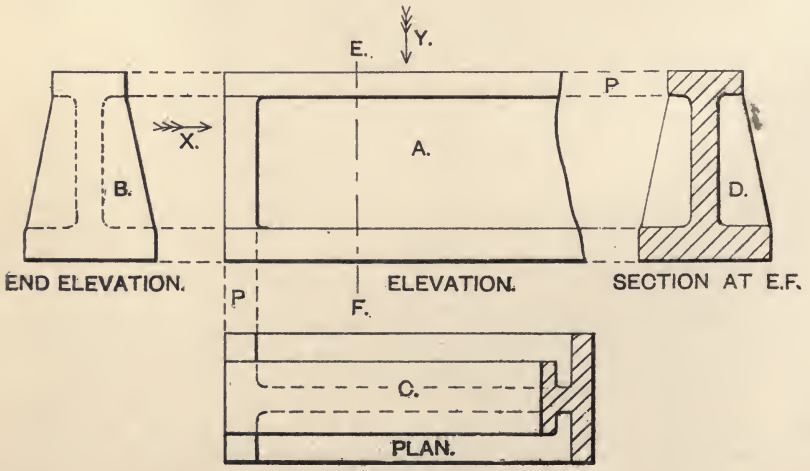


FIG. 1.

The view A is the projection of the beam on a vertical plane parallel to its front and back faces, which shows the *length* and *depth*, this view however does not show the breadth, to do this a view must be drawn at right angles to A, this is shown at B, and is a vertical one, *i.e.* looking in the direction of the arrow X, and shows the *breadth* and *depth*, the depth of course being the same as in the view A. The view C is on a horizontal plane, looking in the direction of the arrow Y and shows the *length* and *breadth*.

The view A is called a "front elevation."
,, ,, B ,, ,, "side or end elevation."
,, ,, C ,, ,, "plan."
,, ,, D ,, ,, "section."

NOTE—In preparing drawings of any object each view must be properly projected one from the other as indicated by the dotted lines marked P on Fig. 1. For the guidance of beginners, projection lines have been inserted in all the examples on Pages 7, 8 and 9, to show how the respective views must be drawn, after a little practice students will find that it is not necessary to show these projection lines, the *centre lines* alone will be sufficient.

SECTIONS.

In preparing machine drawings, elevations and plans, do not always show clearly the construction, so in order to make the parts clear, the detail or object is supposed to be cut through by planes in such directions that the arrangement of the parts is clearly shown. In Fig. 1, the beam is supposed to be cut through by the plane E.F., and the solid parts so cut are "section lined," see view D., these section lines must always be drawn with the angle of 45°. In drawing sectional views it is usual to show rivets, bolts, rods, and shafts (when seen at right angles to their axes) in *outside elevation*, as it will readily be seen that their sections are obvious. The ordinary way of drawing these details is shown on pages 10, 11, 25, 27, etc.

USE OF DOTTED LINES.

If any line in the object drawn cannot be seen from the point at which it is viewed, such a line is shown dotted, an illustration of this will be seen in Fig. 1, views B. and C.

NOTES ON SCALES.

Ivory or boxwood scales are the most serviceable, all the dimensions should be transferred direct to the drawing paper, by placing the scale in contact with it *and not by means of dividers or compasses*, a practice that not only injures the scale, but disfigures the drawing, and occupies too much time. The method of reading the dimensions from scales is shown on page 7.

It is of the utmost importance that all scales should be quite accurate or they are useless.

ARRANGEMENT AND NUMBER OF VIEWS REQUIRED.

In preparing drawings, sufficient views should be drawn to make the design of the machine or its parts quite clear, these should be neatly arranged on the drawing paper, with a suitable space between each view, and not crowded together or near one edge of the paper, a little care at the outset in calculating the space each view will occupy, will prevent *bad arrangement*. Fig. 1 shows how the views are usually arranged in relation to each other.

When an object is symmetrical about a centre line it is usual, in order to save time and space, to show one half in section and the other half in elevation or plan, as illustrated in examples on pages 31 and 59.

The *centre lines* should be clearly shown on all the views.

DIMENSIONS ON DRAWINGS.

A working drawing should be fully dimensioned as well as drawn to scale, so that the workman can readily take his particulars without having to measure up the drawing with his scale or rule, an operation which not only takes time, but also is liable to result in error.

Fig. 2 shows the method generally adopted by draughtsmen in dimensioning drawings.

Overall measurements (*e.g.* $3\frac{5}{8}$″) should always be shown, as well as the dimensions of the different parts.

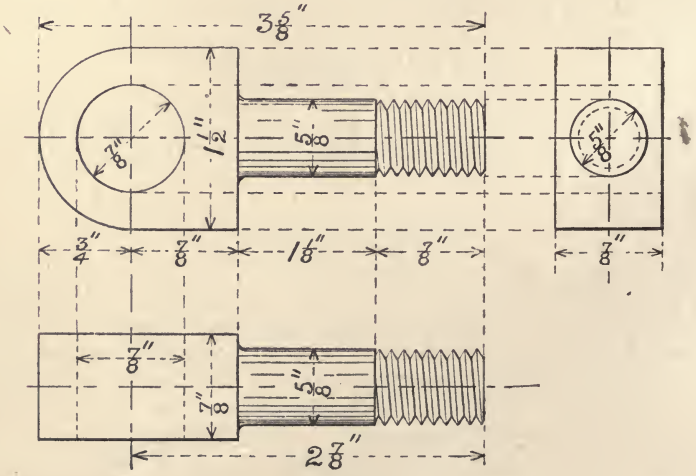


FIG. 2.

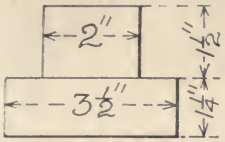


FIG. 3.

In marking the distance between two lines be careful to put the arrow points close to the line as shown at Fig. 3, and *not as in Fig. 4*. If the lines are too close together, the arrow points may be placed on the outside, *see Fig. 5*, but where there is sufficient room they should always be placed inside the lines as in Fig. 3.

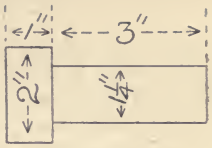


FIG. 4.

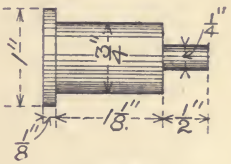


FIG. 5.

TRACING AND PHOTO-PRINTING.

In many drawing offices the usual procedure is to keep the drawings in pencil, and to make the tracings in ink, from which photo or "Blue-prints" are made. In making tracings care should be taken to get the lines of uniform thickness, and to make the joints neatly where a straight line joins an arc of a circle. Some offices favour one thickness of lines throughout the tracing, whilst in others two thicknesses of lines are used in the same tracing, as shown at Fig. 1. (*See notes on back-lining* page 6.)

Great care should be taken to *see that the Indian Ink is properly black* if good "prints" are to be obtained. Original tracings should be made on good paper or cloth, and if required to be copied *should not be folded or creased*.

PHOTO-PRINTS may be either printed in a special frame by exposing it to the light, or by means of an Electric Copier, the advantage of the latter system is that copies can be made at any time and in all weathers.

The following are brief instructions for printing "white lines on a blue ground," viz:

Place the tracing to be copied in the frame with the face next to the glass, and place over it a sheet of Ferro-Prussiate paper, *(about an inch larger than the tracing)*, then put on the back a sheet of felt, and fix the frame by means of the clamps or clips, and expose it to the light *until the print becomes a dark olive tint*. The time of exposure varies according to the weather. After sufficient exposure the print is taken from the frame and immersed in a bath of cold water and left for a short time, it is then taken out and hung up to dry, after which it is ready for use.

INKING-IN AND FINISHING DRAWINGS.

After completing the drawing in pencil, if required it can be inked-in with Indian-ink and the parts in section coloured, the centre lines should be drawn in red ink continuous, not dotted (crimson lake colour is often used) and the dimension lines in blue ink (prussian blue colour), the arrow points < > and figures should be in Indian-ink.

The title of the drawing should be neatly printed in block letters and "elevation," "plan," or "section," printed under the respective views (*see* example on page 35). The scale must also be clearly shown.

Remember to always ink curves and circles in first.

The following are examples of letters and figures which may be used on drawings and tracings for titles, headings and dimensions :—

A B C D E F G H I J K L M N O P
Q R S T U V W X Y Z
1 2 3 4 5 6 7 8 9 0

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
1 2 3 4 5 6 7 8 9 0

For making remarks on drawings, Italic letters similar to the following are very often used by draughtsmen.

a b c d e f g h i j k l m n o p q r s t u v w x y z

LINE SHADING AND COLOURING.

(1) *Backline Shading.* A drawing is greatly improved by back-lining or line shading, *i.e.*, making the right-hand side and bottom lines rather thicker (*see* Figs. 1 and 3), round parts may also be lightly shaded to make them clearer as shown at Fig. 5.

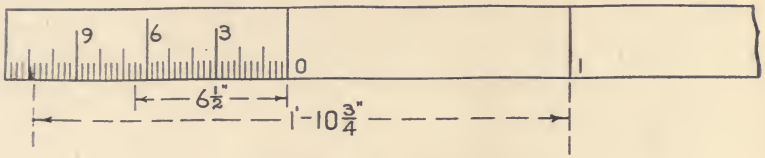
(2) *Colouring.* Water colours are often used to indicate the Metals employed in the construction of the different parts of machines. The following table shows the colours used by engineers for the various materials.

Material.	*Colour.*
Cast Iron	Payne's Grey, or neutral tint.
Wrought Iron	Prussian Blue.
Steel	Purple, mixture of prussian blue and crimson lake.
Brass and Gun-metal	Gamboge.
Copper	A mixture of crimson lake and gamboge.
Wood	Burnt Sienna.
Stonework	Yellow Ochre, and sepia.
Brickwork	Crimson Lake.

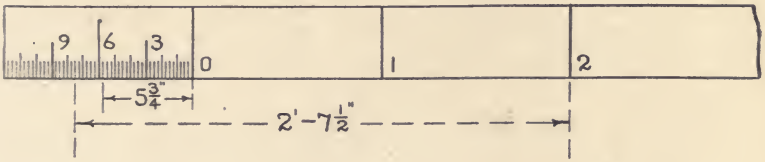
SCALES.

The following diagram shows two scales frequently used in drawing offices, viz: $1\frac{1}{2}$" and 1" to the foot. The method of reading the dimensions is clearly indicated, and the measurements should be transferred from the scale direct to the drawing paper by a finely sharpened pencil. Practice will soon enable a student to confidently handle any scale.

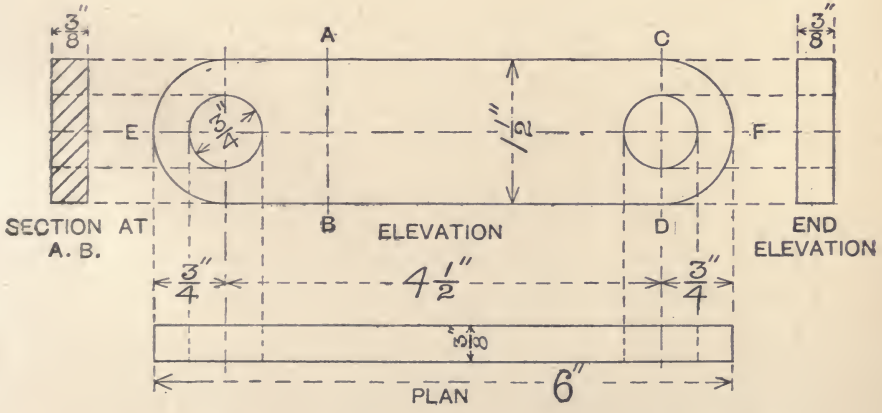
SCALE. $1\frac{1}{2}$" = 1 FOOT.



SCALE. 1" = 1 FOOT.



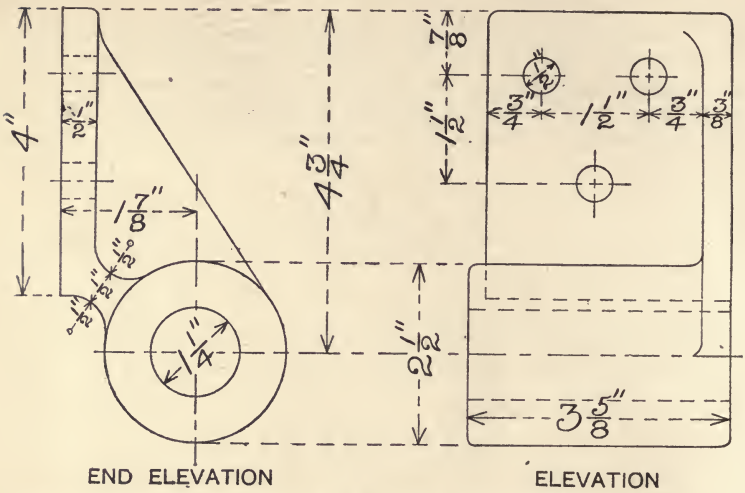
DRAWING OF LINK PLATE.



Draw the four views of link plate full size, and add two sections, one at C.D. and the other through E.F.

Metal—Wrought Iron.

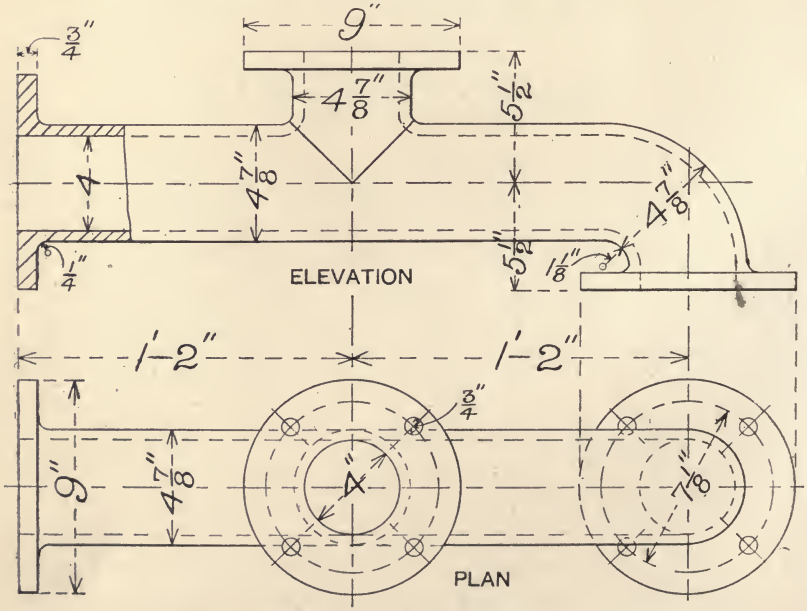
BRACKET FOR CARRYING SHAFT OR SCREW.



Draw this Bracket full size, and add a plan view.

Metal—Cast Iron.

BRANCH AND ELBOW PIPE.

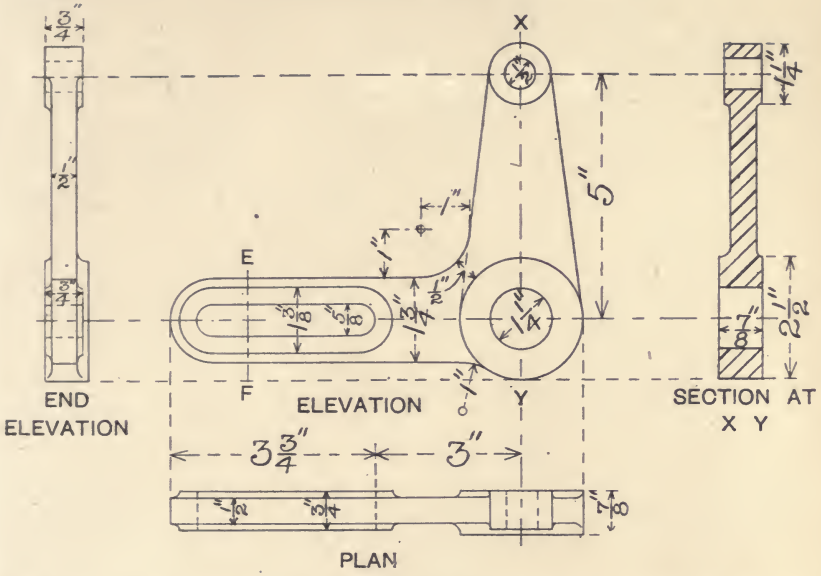


Draw this example to scale, 3″ = 1 foot. Add a sectional elevation, and two end elevations.

Metal—Cast Steel.

BELL CRANK LEVER.

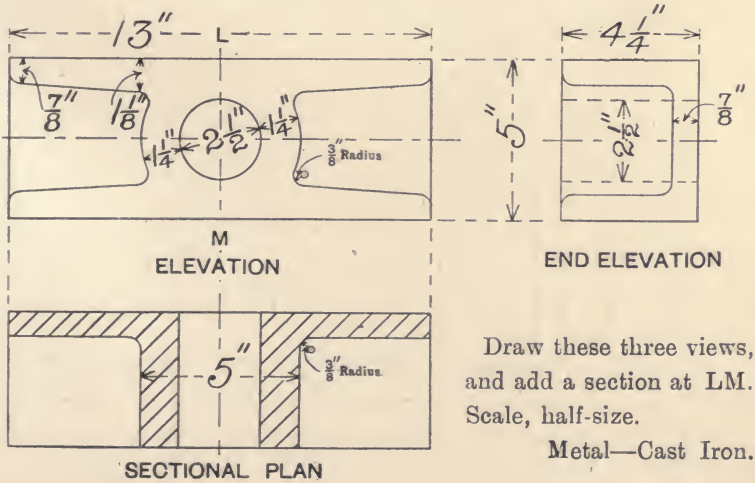
(86)



A Bell Crank lever is used for transmitting a small amount of motion at right angles. The above example is used for working the "*feed motion*" in a Shaping Machine.

Draw the four views as shown, and add a section through EF. Scale Full Size. Metal—Wrought Iron or Steel.

SLIDE BLOCK FOR STEAM ENGINE.

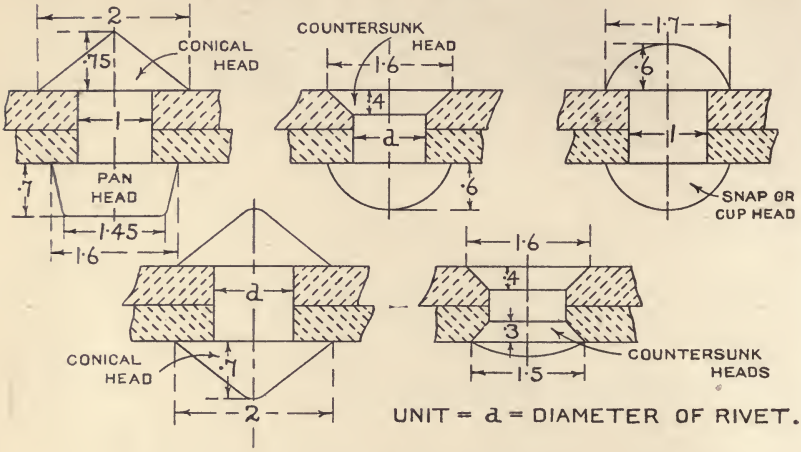


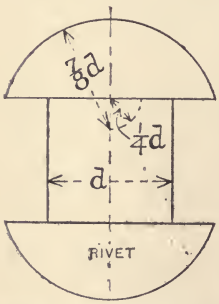
Draw these three views, and add a section at LM. Scale, half-size.

Metal—Cast Iron.

RIVETED JOINTS.

(1) Make neat Sketches showing the different forms of finished Rivets employed for joining Boiler Plates, &c.



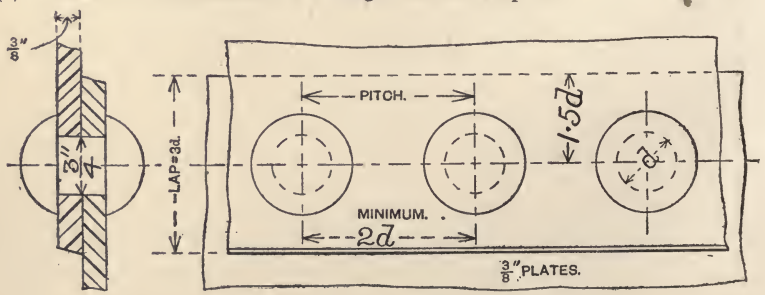


Rivets are the simplest form of permanent fastenings, and can only be removed by chipping off the heads. The length of rivet required to form a cup or conical head is about $1\frac{1}{4}$d, and about $\frac{7}{8}$d for a countersunk head. The rivet holes are made $\frac{1}{16}$" larger in diameter than the rivet to allow for expansion when the rivet is heated. Drilling has practically superseded punching for the rivet holes in boilers. It is more accurate, gives a cleaner hole and does not injure the plate. The Board of Trade require steel plates to have a tensile strength of 28 tons per square inch, and steel rivets a shear strength of 23 tons per square inch. For Wrought Iron, the tensile and shear strengths are the same, viz: about 21 tons per square inch. The diagram to the left shows the graphical method of setting out a cup head rivet.

Let d = dia. of rivet and t = thickness of plates.

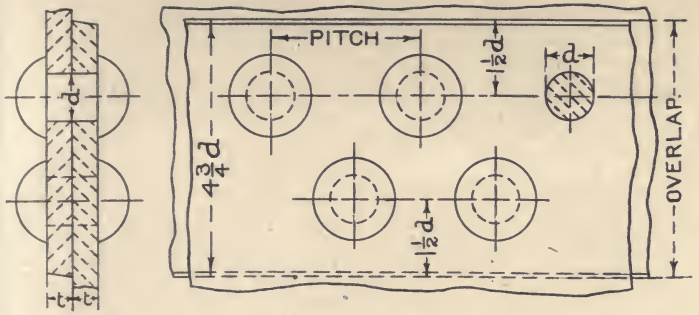
For plates $\frac{3}{8}$" thick and less d = 2t.

(3) Show the construction of a Single Riveted Lap Joint.



SINGLE RIVETED LAP JOINT.

For Wrought Iron.	Dia. of Rivets = t + $\frac{3}{8}$".	Pitch = $2\frac{1}{4}$d.
For Steel.	Dia. of Rivets = t + $\frac{7}{16}$".	Pitch = $2\frac{1}{8}$d.

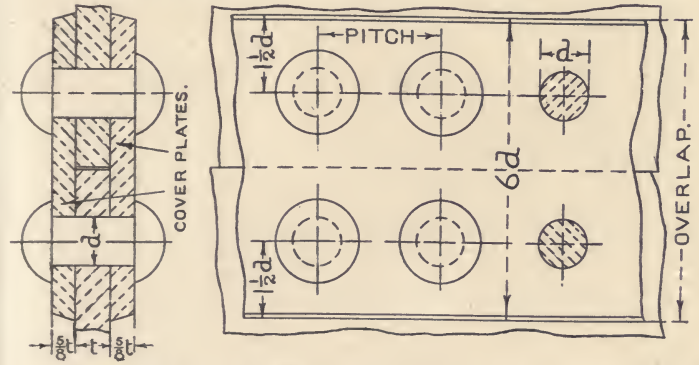


EXAMPLE:—

½″ Steel Plates.
Rivets ⅞″ dia.
Zig-zag Riveting.
Pitch 2⅝″.
Overlap 4⅛″.

DOUBLE RIVETED LAP JOINT.—ZIG-ZAG RIVETING.

For Steel—Dia. of Rivets = t + ⅜″. Pitch = 3d.
For Wrought Iron—Dia. of Rivets = t + $\frac{5}{16}$″. Pitch = 3¼d.
For Chain Riveting (see next example) the overlap would be ¾″ to 1″ greater than for Zig-zag Riveting.

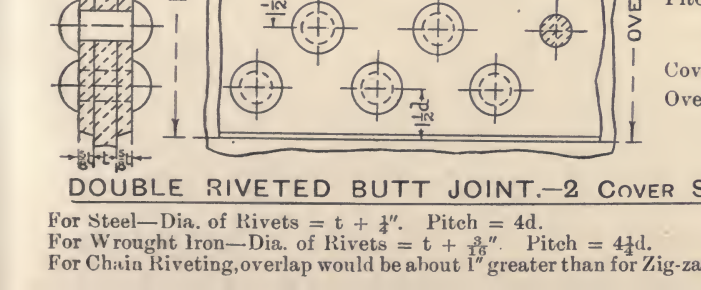


EXAMPLE;—

⅝″ Wrought Iron Plates.
Rivets ⅞″ dia.
Pitch 2⅜″.
Overlap 5¼″.
Cover Straps or Cover Plates ⅜″.

SINGLE RIVETED BUTT JOINT.—2 COVER STRAPS.

For Steel—Dia. of Rivets = t + $\frac{5}{16}$″. Pitch = 2⅛d.
For Wrought Iron—Dia. of Rivets = t + ¼″ Pitch = 2¾d.
When a single cover plate is used the joint is proportioned similar to two Single Riveted Lap Joints, and the thickness is 1⅛t.



EXAMPLE:—

¾″ Steel Plates.
Rivets 1″ dia.
Pitch 4″.
Zig-zag Riveting.
Cover Plates ½″.
Overlap 10″.

DOUBLE RIVETED BUTT JOINT.—2 COVER STRAPS.

For Steel—Dia. of Rivets = t + ¼″. Pitch = 4d.
For Wrought Iron—Dia. of Rivets = t + $\frac{3}{16}$″. Pitch = 4¼d.
For Chain Riveting, overlap would be about 1″ greater than for Zig-zag Riveting.

The efficiency of a Riveted Joint

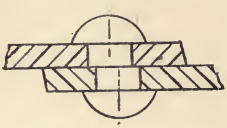
$$= \frac{\text{Strength of plate after drilling}}{\text{Strength of plate before drilling}} = \frac{\text{Pitch} - \text{Dia.}}{\text{Pitch.}}$$

In the last example on page 11

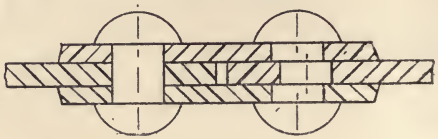
$$\text{Efficiency} = \frac{4-1}{4} = \frac{3}{4} \textit{ i.e. } 75\%.$$

---

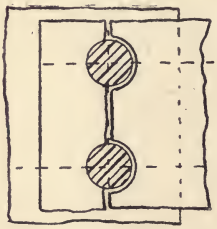
(165) (166) *Show in how many ways a Riveted Joint may give way.



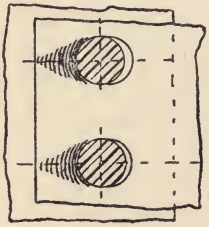
(1) Rivet in single shear.



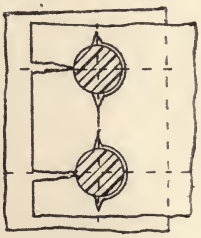
(2) Rivet in double shear.



(3) By the tearing of the plates between the rivets.



(4) By the crushing of the rivets or the plate.



(5) By the breaking of the plate between its edge and the rivet holes.

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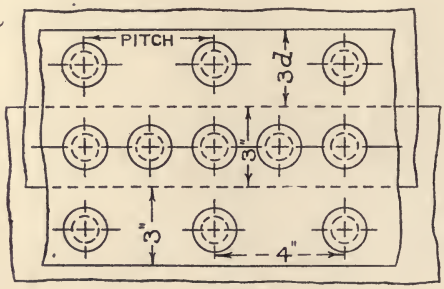
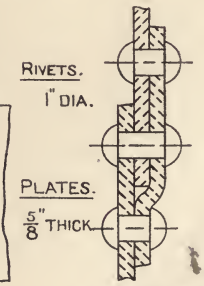
(168) Give sketches showing the construction of a Combined Lap and Butt Joint. Draw out the two views shown. Scale Half Size.



PLAN.



SECTION.

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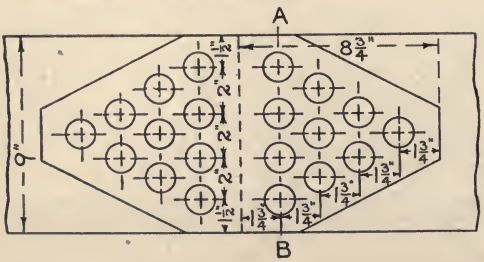
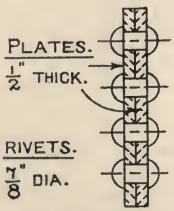
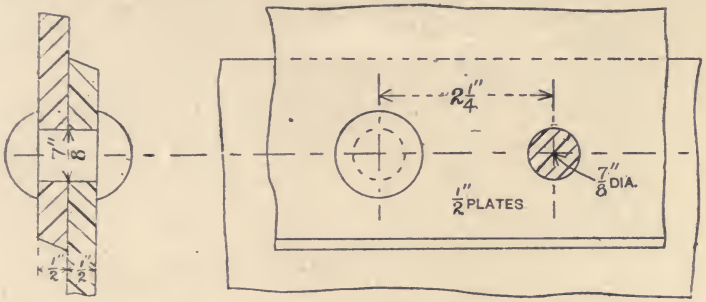
174) Make neat sketches of a "lozenge" joint employed for connecting two plates of a Girder, for roof or bridge work. Draw out the two views shown. Scale Half Size.





SECTION AT A.B.

* In a Single Riveted Lap Joint the plates are $\frac{1}{2}$" thick, Rivets $\frac{7}{8}$" diameter, Pitch $2\frac{1}{4}$". Supposing equal areas are required for equal strengths of Rivet and plate, find whether the joint will fracture by tearing or by
(169) Shearing?



Pitch—Dia. of Rivet × thickness = tearing. $(2\frac{1}{4}" - \frac{7}{8}") \times \frac{1}{2}" = \cdot6875$.

Dia.$^2 \times \frac{\pi}{4}$ = shearing. $\frac{7}{8}"^2 \times \cdot7854 = \cdot6013$.

Therefore the joint will fail by shearing.

---

* Two plates, each $\frac{3}{8}$" thick, are to be joined by a Single Riveted Lap Joint. The diameter of the rivets is to be $\frac{3}{4}$". Find the pitch so that the resistance to tearing of the plate between the rivet holes is equal to the resistance of the rivets to shear, assuming that the ultimate tenacity of the plates is 30 tons per square inch and the ultimate shearing strength of the rivets is 24 tons per square inch.

Strength of Plate = (Pitch $- \frac{3}{4}$) $\times \frac{3}{8} \times 30$ ... (1)

Strength of Rivets = $\frac{\pi \times \frac{3}{4}^2}{4} \times 24$ ... ... (2).

(1) equals (2), therefore,

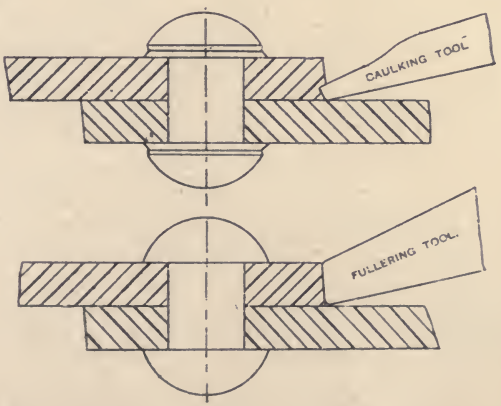
$$(\text{Pitch} - \tfrac{3}{4}) \times \frac{90}{8} = \frac{\pi \times 9 \times 24}{4 \times 16}$$

$$\text{Pitch} = \frac{3{\cdot}14 \times 9 \times 24 \times 8}{4 \times 16 \times 90} + \tfrac{3}{4} = \underline{1\tfrac{11}{16}" \text{ Ans.}}$$

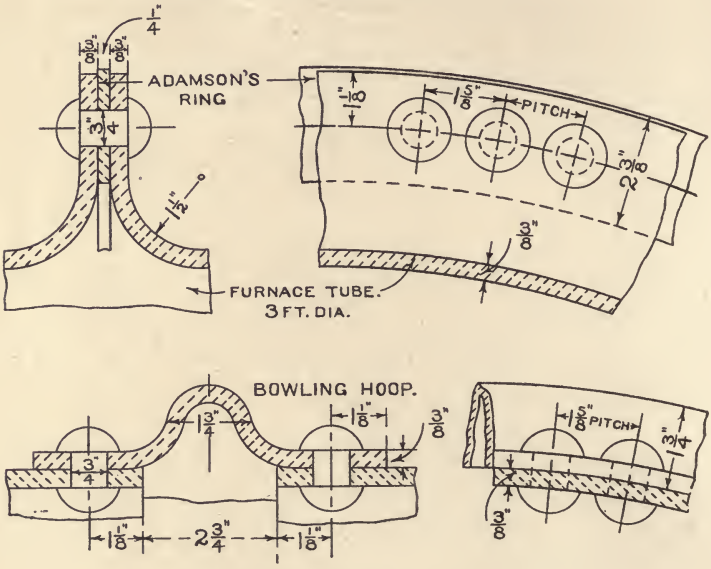
What do you understand by "caulking and fullering" as applied to Riveted Joints for Boiler Plates.

(175)

If the Joints in a Boiler are not steam tight, they may be rendered so by "caulking," that is burring down a narrow strip of the plates and rivets, or a "fullering" tool may be used. See sketches.



(4). Boiler Flue Plates are fastened together by means of Adamson's Rings, or Bowling Hoops. Show by sketches how this is done, and explain the use of same.



FURNACE TUBES, 3ft. DIA.

THESE JOINTS ARE USED FOR CONNECTING THE FURNACE TUBES OR FLUES IN BOILERS; THEY ALLOW FOR THE EXPANSION OF THE TUBES BY HEATING, AND THUS PREVENT COLLAPSE.

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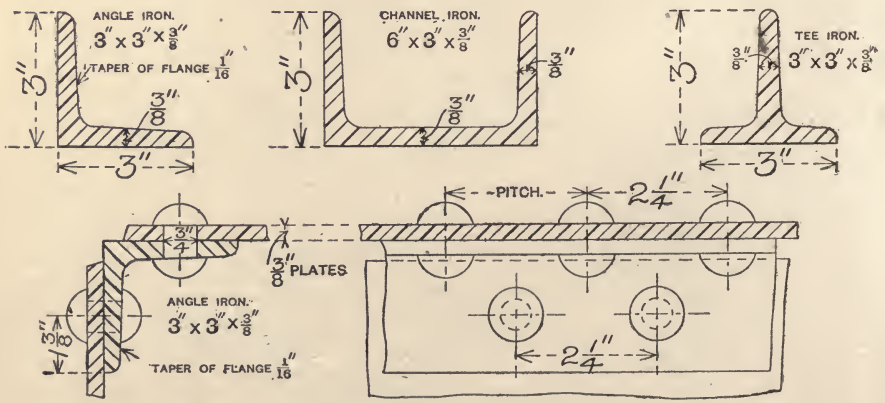
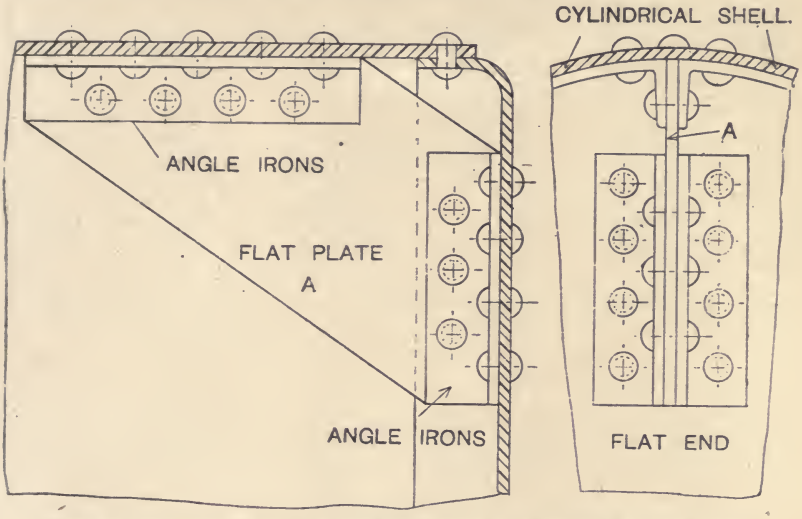
(5). *Sketch sections of Angle, Tee and Channel Iron. Give two views showing how two Wrought Iron Plates are connected together at right angles to one another by means of angle iron and rivets.

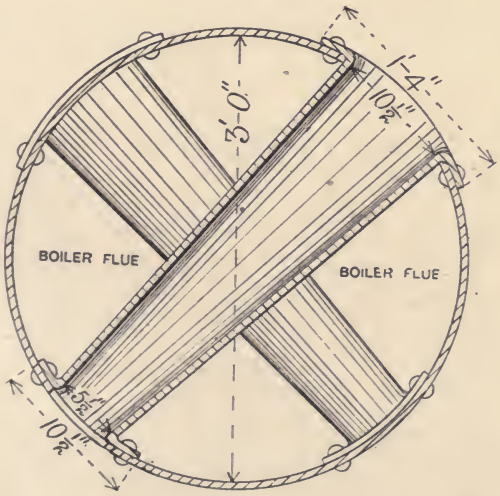


*Give sketches of a "Gusset" stay employed in the construction of
(172) Steam Boilers; what is the object of the same?



Used in Lancashire and Cornish Boilers for staying the flat end plates to the cylindrical shell.

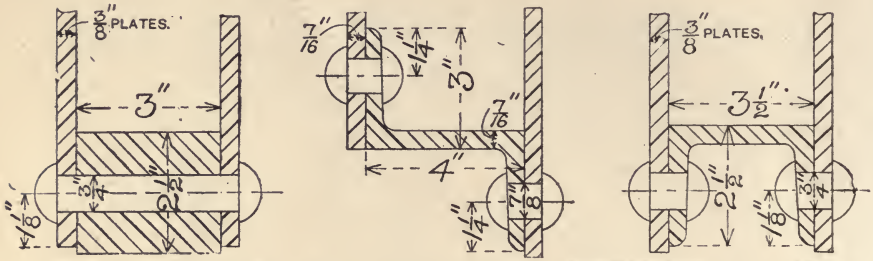
Make sketches of "Galloways" water tubes for Steam Boilers
(177) showing clearly how they are fixed to the furnace tubes.



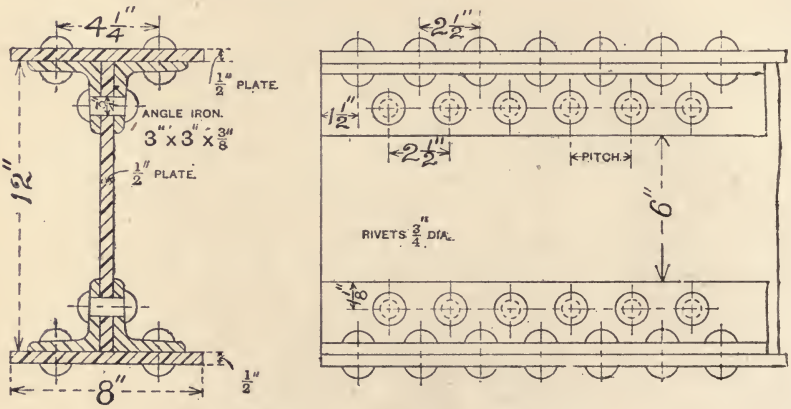
Besides adding considerably to the heating surface of a Boiler, "Galloways" Tubes also strengthen the furnace tubes and cause a better circulation of water.

Supplied by Messrs. GALLOWAYS' Limited.
Engineers and Boiler Makers, MANCHESTER.

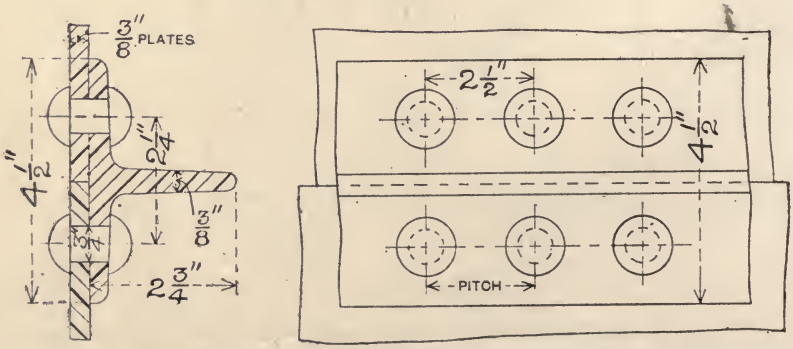
It is required to connect parallel plates together such as are used in Locomotive Fire Boxes. Show three methods of doing this.
(6)



Give sketches showing the construction of a Wrought Iron Plate Girder. Draw out this detail. Scale Half Size.
(173)



Give sketches showing the construction of a T iron Joint and give examples of its use.
(8)

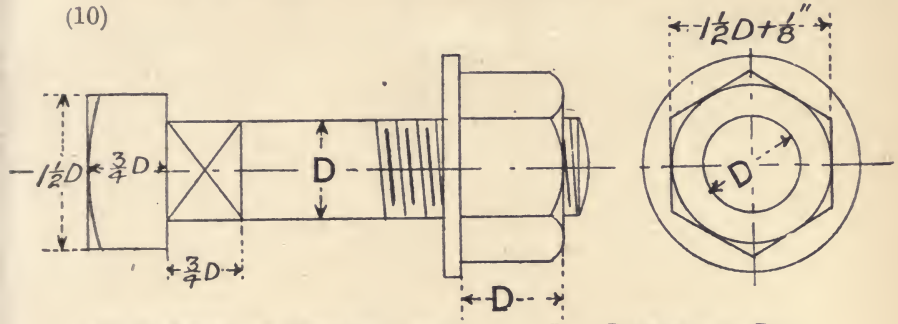


USED IN BOILER, BRIDGE AND TANK WORK FOR STIFFENING PLATES.

BOLTS, NUTS, AND SCREWS.

Sketch a Bolt with a square head and hexagon nut, and mark on the usual proportions. Draw a $\frac{3}{4}$" dia. bolt and nut. Scale Full Size.

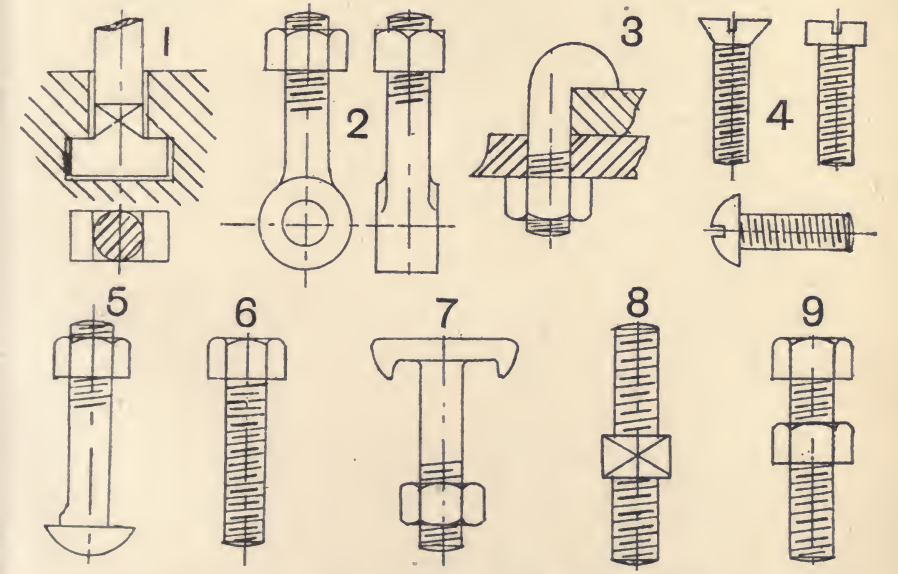
(10)



The Diameter of Washers = $2\frac{1}{4}$ D. D = Diameter of Bolt.
,, Thickness ,, ,, = $\frac{3}{20}$ D.

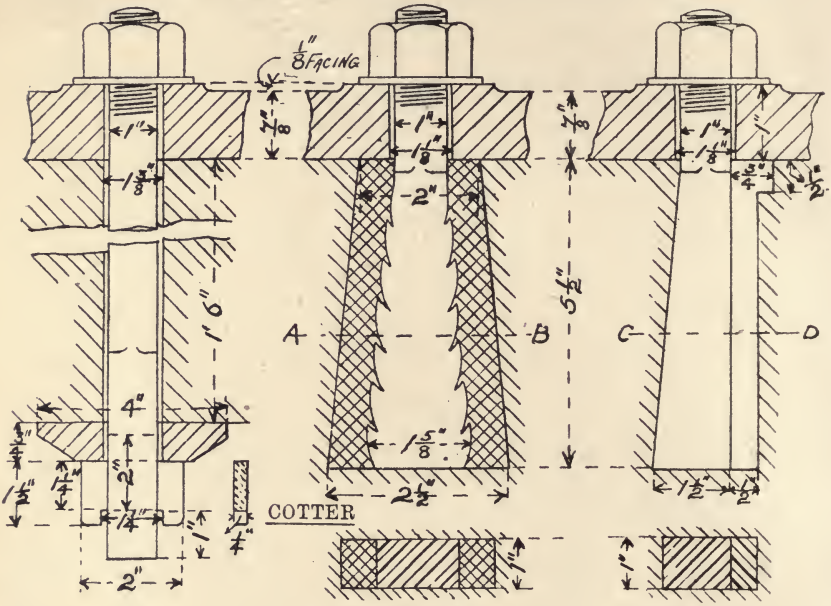
Make sketches showing (1) T Head Bolt (2) Eye Bolt (3) Hook Bolt (4) Screws (5) Cuphead Bolt (6) Set Screw (7) Fang Bolt (8) Stud (9) Set Bolt.

(12)



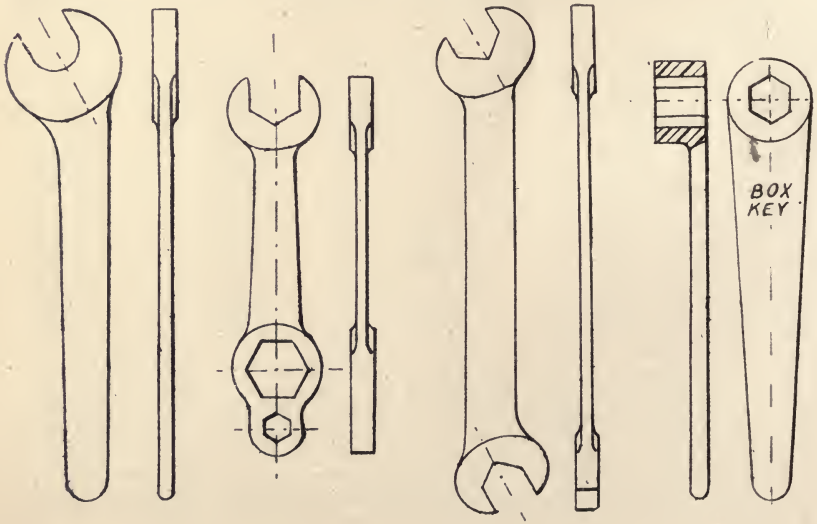
A bolt may be prevented from rotating, when screwing up the nut. by a square on the shank just under the head, or by a lug or pin, which fit in a corresponding recess in the casting. A *stud or stud bolt* is screwed at both ends, one end enters the material and the other receives the nut. A *tap bolt* is a bolt with a head, and is screwed into one of the pieces to be connected while the head presses on the other piece. *Studs and screws* should never bear against the bottom of the holes into which they are screwed, and the distance from the edge of the metal must not be less than $\frac{5}{8}$ D to D. D = dia.

Show the three forms of Bolts usually employed for securing Engine Beds, &c., to stone foundations, viz:—(1) Cotter Bolt; (2) Rag
(14) Bolt; (3) Lewis Bolt; and show how they are fixed in position.



COTTER BOLT. Section at A.B. RAG BOLT. Secton at C.D. LEWIS BOLT.

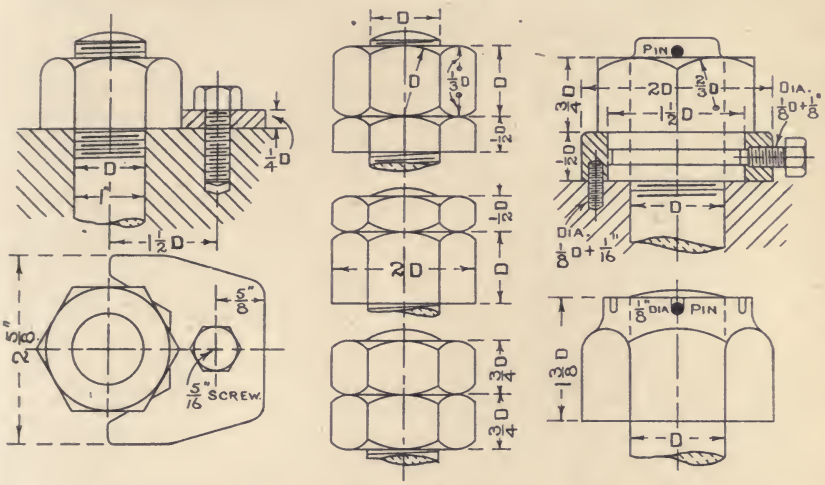
Make sketches showing two or three forms of spanners used for
(19) tightening up bolts and nuts, also show a box key.



LOCKNUTS.

In Machinery, Nuts are liable to work loose by vibration. Sketch two or three methods showing how to prevent a Nut from working loose.

(15)



In the first example above, the nut is locked by a plate and screw, the plate being cut out to fit the points of the nut. In the ordinary locknuts, the top one is correct practice, but as a thin spanner must be used to operate the nut, the next example is more frequently used. The bottom one is a compromise between the two. The nuts in the two right hand examples are secured by pins and set screws.

See also pages 56, 57, 61, 64, etc., for examples of locknuts.

---

*What are the various ways in which a screwed Bolt and Nut may yield to the forces to which they are subjected? Give the dimensions of the Nut and screw thread of an inch Bolt.

(182).

ANSWER. The thread may strip off the bolt, or out of the nut, or partly from each. The bolt may break at the junction of thread and shank, or close under the head, or at any other point throughout its length. The nut may burst through the weld. The head may pull off through the collar weld with which it was formed. The nut may be so stiff upon the threads that the bolt may fail by torsion in screwing up the nut; or, if rusted on, in unscrewing it. In work, the bolt may fail by tension or shearing. An inch nut is 1 inch thick, $1\frac{5}{8}$" across the flats, has eight threads per inch.

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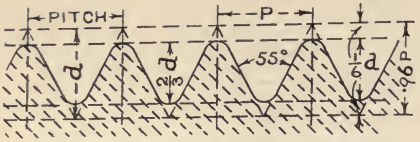
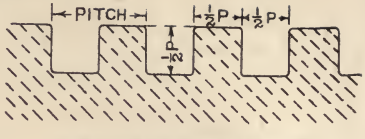
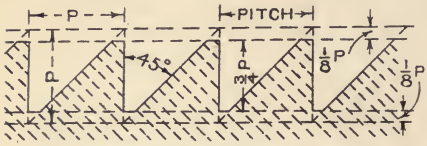
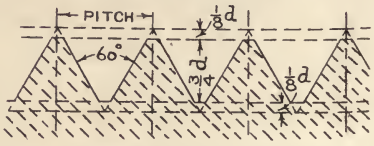
*Make a freehand sketch of a longitudinal section of a Whitworth Bolt, 1" diameter, showing the true shape of the thread sixteen times full size.

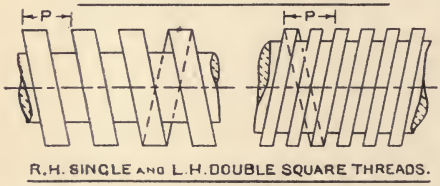
SCREW THREADS.

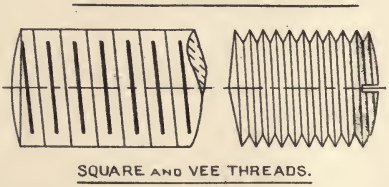






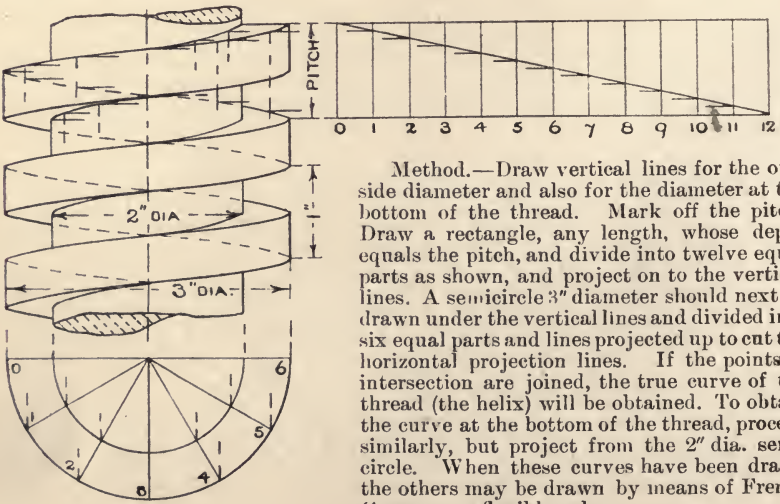






The *Whitworth Thread* is the standard triangular thread used in the British Isles. The friction of the thread is very great, owing to the force exerted on the thread reacting at right angles to its face, thus tending to burst the nut. It has great strength to resist shearing action. In the *Square Thread* the reaction acts parallel to the axis of the screw, thus friction is reduced and there is no tendency to burst the nut. The shearing strength is half that of the Vee thread. Guide screws have the sides of the thread tapered slightly so that the half nuts may be readily engaged or disengaged. The *Buttress Thread* is designed to combine the advantages of the Vee and the Square threads, without their defects. Great pressure may be exerted in one direction only. The *Sellers Thread* is the standard triangular thread used in America. The four bottom diagrams show the usual way of indicating screw threads.

A Square Thread Screw is 3″ outside diameter and 1″ pitch. Draw out correctly three threads of this screw.

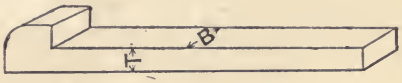


Method.—Draw vertical lines for the outside diameter and also for the diameter at the bottom of the thread. Mark off the pitch. Draw a rectangle, any length, whose depth equals the pitch, and divide into twelve equal parts as shown, and project on to the vertical lines. A semicircle 3″ diameter should next be drawn under the vertical lines and divided into six equal parts and lines projected up to cut the horizontal projection lines. If the points of intersection are joined, the true curve of the thread (the helix) will be obtained. To obtain the curve at the bottom of the thread, proceed similarly, but project from the 2″ dia. semicircle. When these curves have been drawn the others may be drawn by means of French Curves or a flexible rule.

KEYS AND COTTERS.

(26) What are the usual proportions of Keys used for fastening wheels and pulleys on to shafting?

PROPORTIONS.



Let D = Diameter of Shaft.

,, B = Breadth of Key ... ... = $\frac{D}{4}$ + $\frac{1}{8}$″

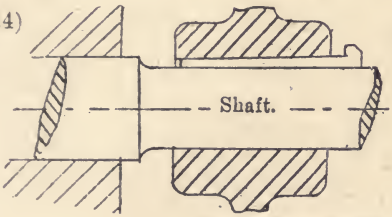
,, T = Mean Thickness of Key = $\frac{D}{8}$ + $\frac{1}{8}$″ for Sunk Key.

,, ,, = $\frac{D}{10}$ + $\frac{1}{16}$″ for Key on flat and Saddle Key.

Taper varies from 1 in 64 to 1 in 96.

What is the object of making a key or cotter with a head on?

(24)



SO THAT IT CAN BE READILY WITHDRAWN WHEN IT CANNOT BE DRIVEN OUT FROM THE POINT END. *(See Sketch).*

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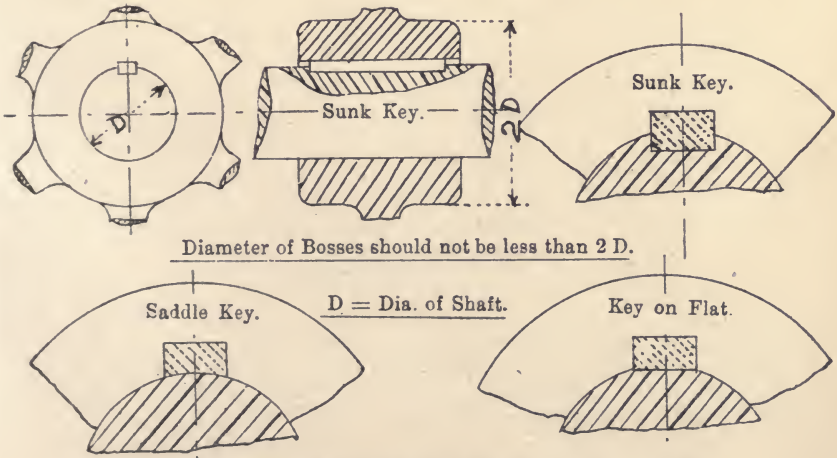
(21) Show by sketches how to fasten a wheel or pulley on to a shaft by means of (1) Sunk Key, (2) Saddle Key, (3) Key on flat.

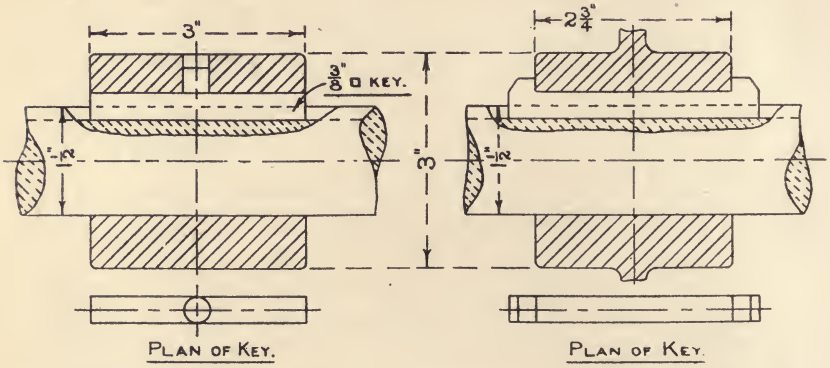


The Saddle Key is used for transmitting a small amount of power.
The Key on Flat is more secure than Saddle Key.
The Sunk Key is adopted where considerable power has to be transmitted.

*Make a freehand sketch of the boss of a spur wheel in place on a shaft 2″ diameter and show in detail the way you would secure the wheel to the shaft.

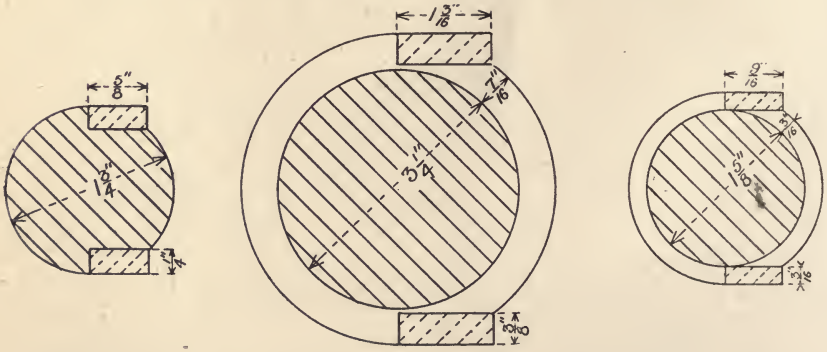
---

(29) Sketch one or two forms of Feather Keys suitable for a "Sliding Motion" such as in the back shaft of a Lathe.



In Feather Keys, the depth usually equals the breadth, and the Keys have no taper.

HOLROYD SMITH'S PATENT KEY.



These Keys are 2½″ long and hold a clutch tight on a shaft.

Speed 1,000 revs. per min.

These Keys are 3½″ long and hold a wheel firm upon an axle.

Speed 100 revs. per min.

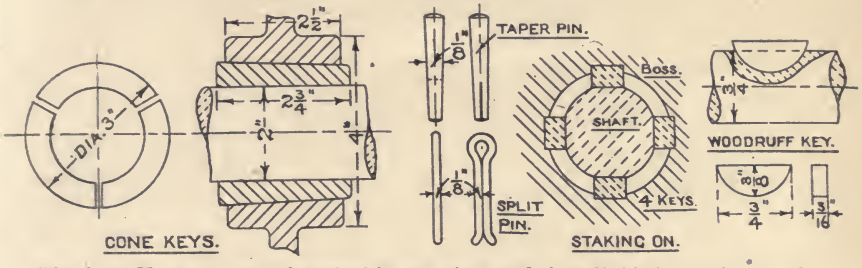
These Keys are 6″ long and drive a worm free to slide to and fro on a Spindle.

Speed 850 revs. per min.

Supplied by

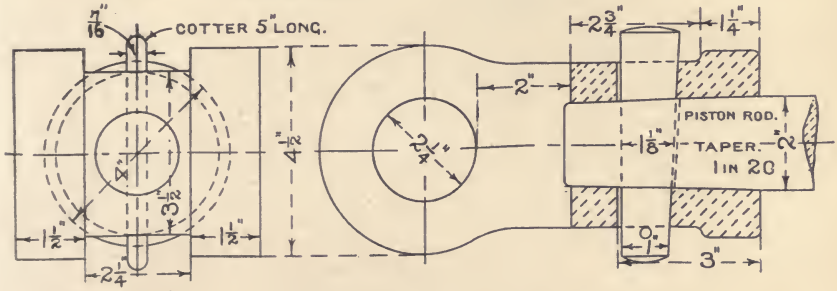
Mr. M. HOLROYD SMITH, M.I.M.E., M.I.E.E.,
Consulting Engineer, Westminster, S.W.

(20) Give sketches of (1) Cone Keys, (2) Taper and Split Pins,
(22) (3) Staking on, (4) Woodruff Key.
(194)



The Cone Keys are turned conical in one piece and then divided into three and driven on to the shaft. Pins are used to lock nuts, and also prevent light wheels from working off their shafts. In "Staking on" four keys are generally used for flywheels, and the boss stands clear of the shaft. The Woodruff Key is used for light work such as change wheel studs, etc.

Give sketches showing how you would fix a Piston Rod to a Cross-head by means of a Cotter. Draw these two views and also
(196) a plan. Scale ¾ size.



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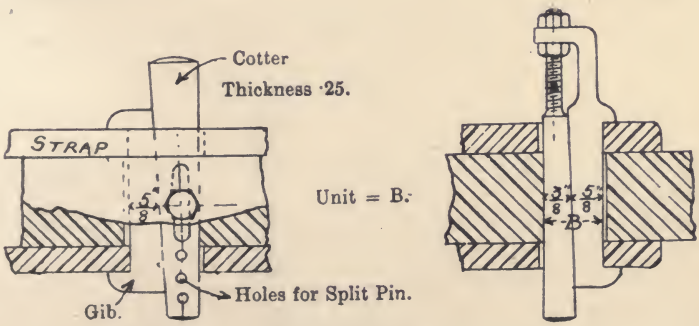
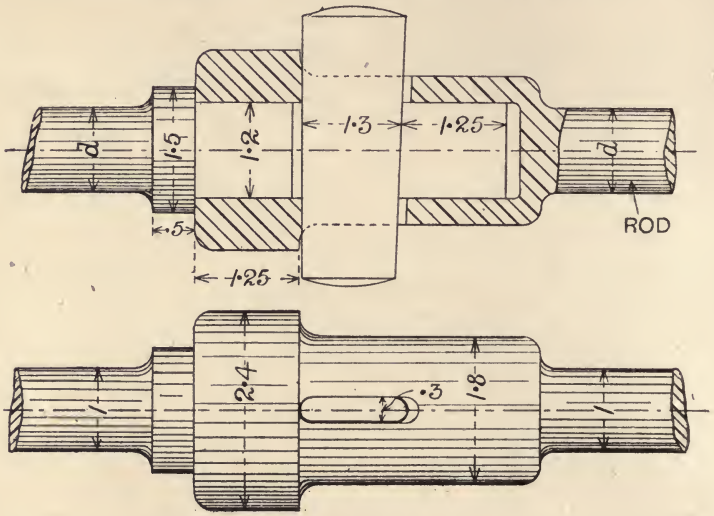
*Show two methods by which a Cotter may be prevented from slacking back.
(28)



See Pages 58 and 59 for Examples.

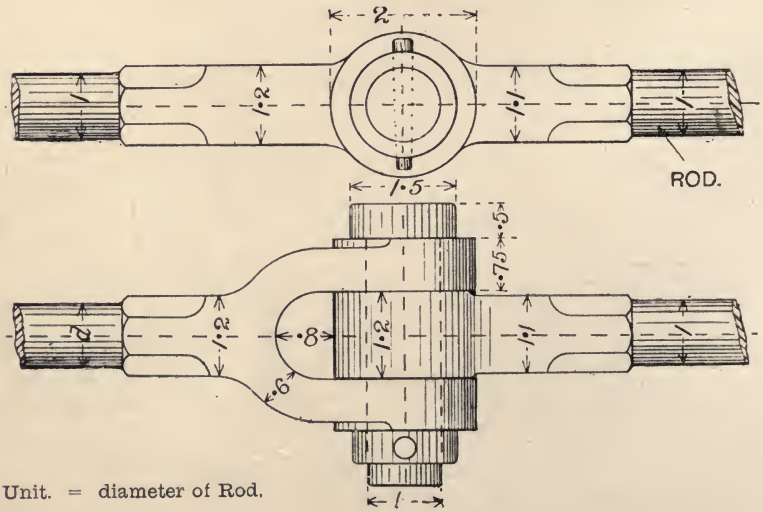
Make sketches of a "Cottered Joint" suitable for connecting separate lengths of pump rods, valve rods, etc., and mark on the usual proportions of same. Design a Joint for $1\frac{1}{4}$" dia. Rods.



Cotter. Width = 1·3 d.
" Thickness = ·3 d.
" Taper = 1 in 24 or $\frac{1}{2}$" per foot.
Unit. = diameter of Rod.

Give two views of a Knuckle or Fork Joint, and mark on your sketch suitable proportions for same. Design a Joint suitable for $1\frac{1}{2}$" dia. Rods.

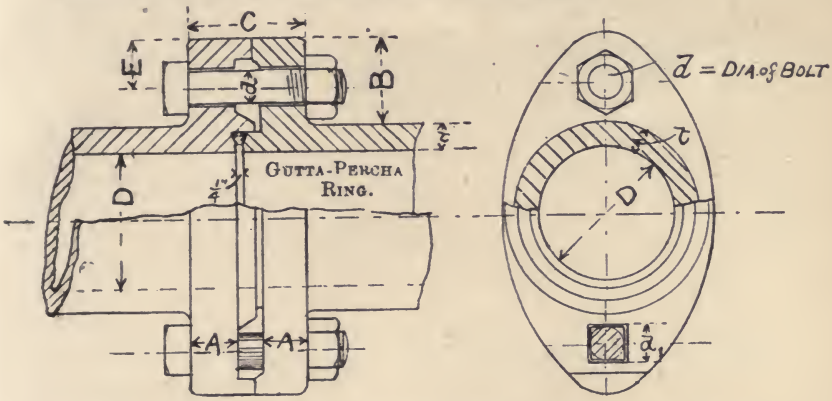
(247)



Unit. = diameter of Rod.

PIPES AND PIPE JOINTS.

Show the construction of a Pipe Joint suitable for hydraulic work, and mark on the proportions for same. Design a Joint for a 4" dia. Pipe to withstand a pressure of 750 lbs. per square inch. (See next page.)



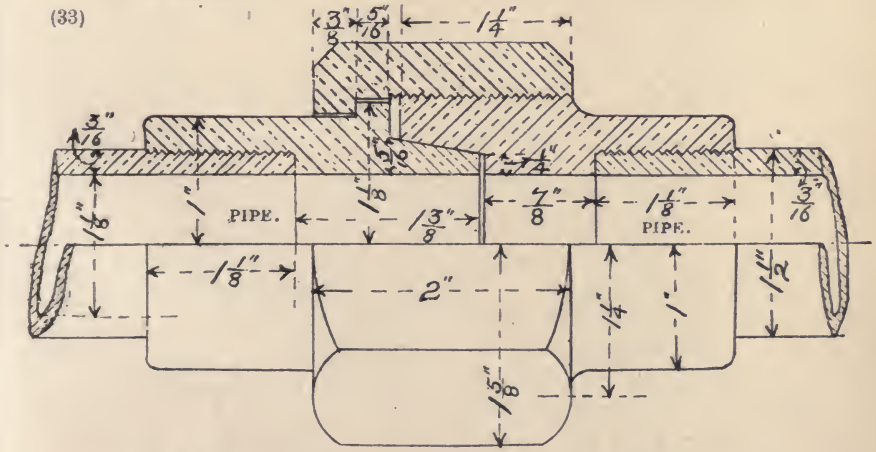
SQUARE HOLES ARE CAST IN THE FLANGE TO PREVENT THE BOLTS FROM TURNING WHILST SCREWING UP THE NUT.

PROPORTIONS. [See Page 26.]

t = Thickness of Pipe.	A = 2t	E = $1\frac{1}{2}$t + $\frac{3}{8}$"
D = Internal Dia. of Pipe.	B = $2\frac{1}{2}$t + $\frac{3}{4}$"	d = $1\frac{1}{4}$t
	C = 4t + $\frac{1}{2}$"	d_1 = d + $\frac{1}{8}$"

*Sketch partly in section a Union Nut and Joint for connecting two lengths of small piping.

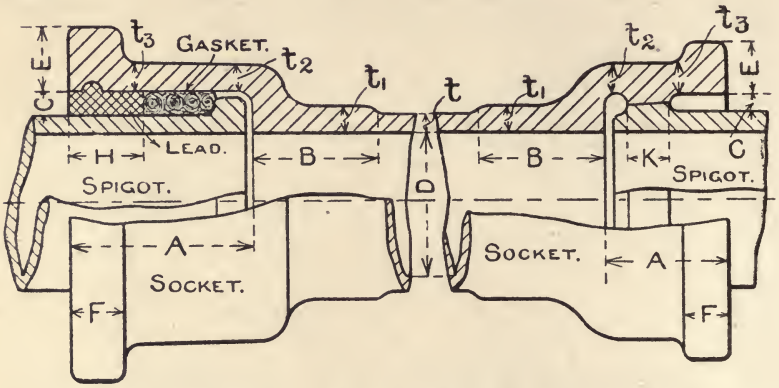
(33)



DRAW THIS EXAMPLE FULL SIZE, AND ADD AN END ELEVATION.

*Two pieces of copper steam pipe, each $1\frac{1}{2}$" diameter and 0·1" thick, are to be connected by a gun metal union joint. Make a freehand sketch of the joint, showing clearly how the joint is made steam tight.

(37) Give sketches showing two methods of constructing Socket and Spigot Joints for large diameter water pipes.



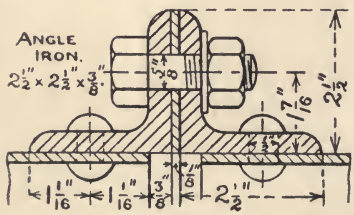
In the right hand example the parts marked K are turned taper to an angle of 1 in 32, and coated with red lead before being put together.

—— RULES AND PROPORTIONS. ——

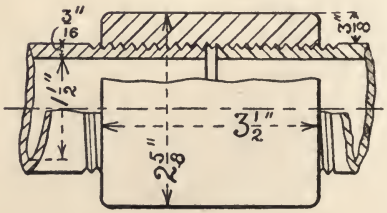
The thickness t of the pipe is determined by this formula, viz:— $t = \frac{PD}{4000} + \cdot 3$, where D = internal diameter of pipe in inches, and P the pressure of water in pounds per square inch. The other dimensions may be obtained from the following rules, all the dimensions being in inches.

$t_1 = 1 \cdot 1\ t + \cdot 07$	$A = \cdot 1D + 2 \cdot 75$	$E = \cdot 045D + \cdot 8$
$t_2 = \cdot 025D + \cdot 375$	$B = \cdot 09D + 2$	$F = \cdot 04D + \cdot 7$
$t_3 = t_2 + \frac{1}{8}$	$C = \frac{1}{4}$ to $\frac{1}{2}$	$H = \cdot 06D + 1$
		$K = \cdot 05D + 1$

(39) Show two methods of connecting the separate lengths of wrought iron or steel pipes.



FLANGED JOINT.

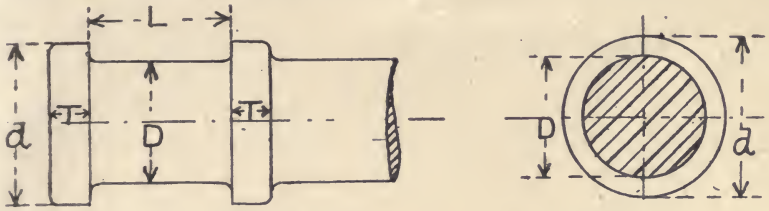


SCREWED SOCKET.

*Sketch a Flange Joint suitable for connecting two 4″ steam pipes carrying steam at a pressure of 120 lbs. per square inch.

SHAFTING, COUPLINGS AND CLUTCHES.

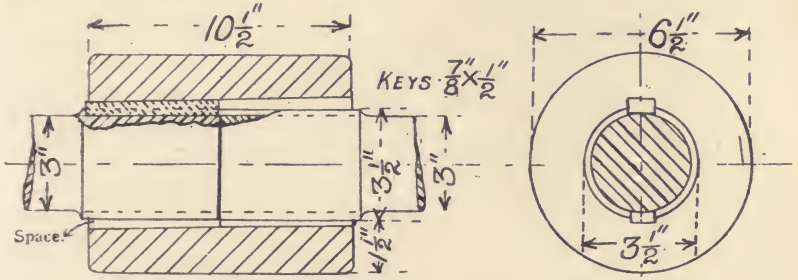
Show the usual form of Shaft "neck" or Journal, and explain the use of same. Mark on your sketch the usual proportions of
(40) a Journal for an ordinary shaft.



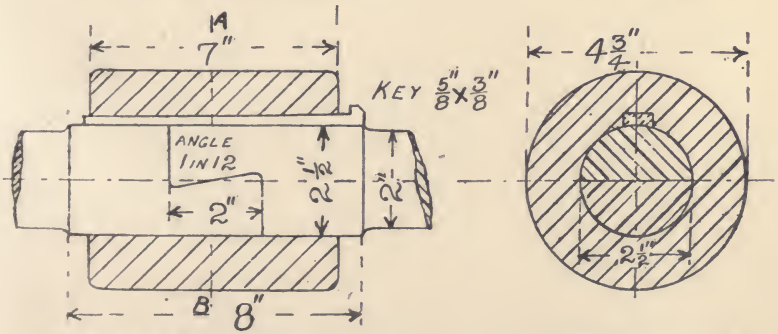
D = Dia. of Shaft. L = $1\frac{1}{2}$D.
d = $1\frac{1}{4}$D to $1\frac{3}{8}$D. T = $\frac{1}{4}$D.

The object of a "Neck" or Journal is to prevent "end play" of the shaft.

Give sketches showing how the separate lengths of a line of Shafting may be connected together. Draw out these examples.
(42) Scale Half Size.



Butt or Muff Coupling. End View.



Half Lap Coupling. Section at A.B.

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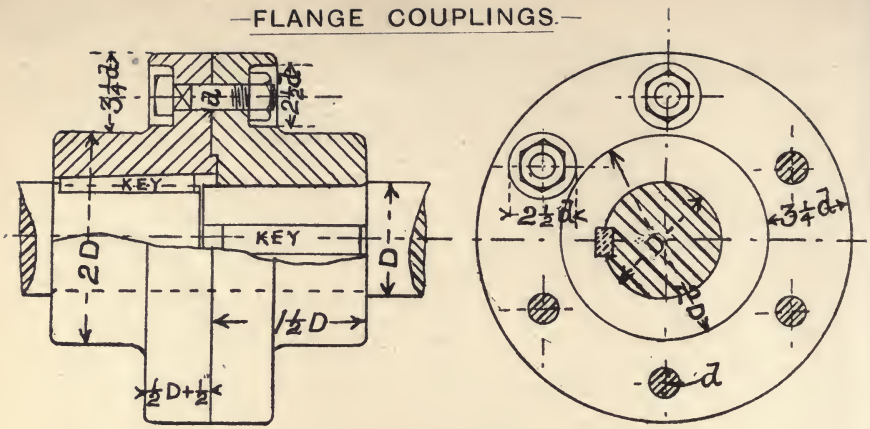
*Sketch in good proportion, giving a few leading dimensions, a muff or box coupling for the connection of two lengths of a machine shop shaft, 3" diameter.

—FLANGE COUPLINGS.—

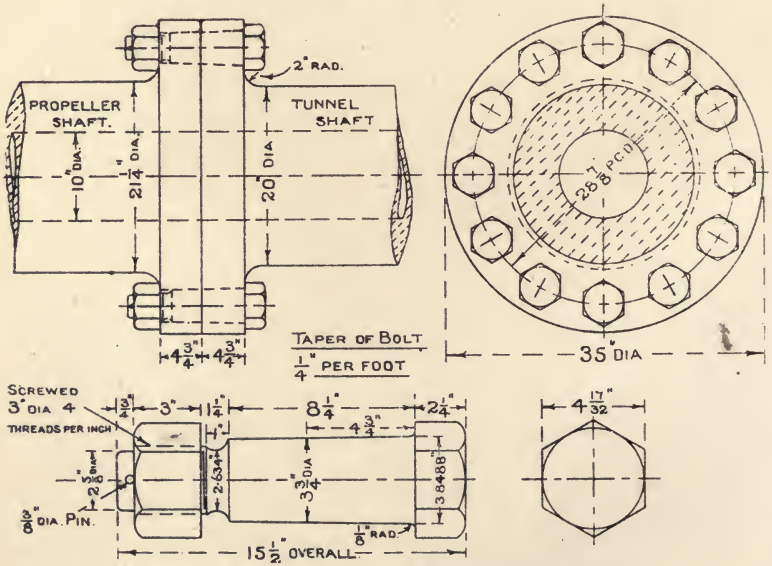


No. of Bolts :—3 Bolts are used for shafts less than 2″ diameter ; above 2 but less than 4″ diameter, 4 Bolts ; from 4″ to 8″ diameter, 6 Bolts.

Diameter of Flange Bolts $= \frac{\text{Diam. of Shaft.}}{\text{No. of Bolts.}} + \frac{1}{4}''$ (Unwin).

It will be noticed that the nuts and bolt heads are let into circular recesses, thus avoiding projections liable to catch a workman's overalls when working near the coupling. A box key is used to tighten up the nuts, similar to the one shown on page 18.

— PROPELLER SHAFT COUPLING.—



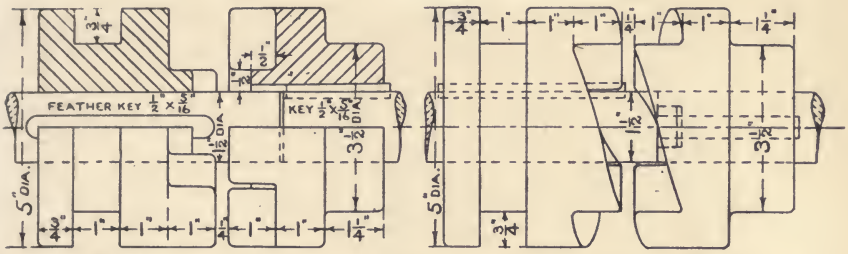
From the Royal Mail Quadruple Screw Turbine Steamers
"LUSITANIA" and **"MAURETANIA,"**
By permission of the Cunard Steamship Co., Ltd., Liverpool.

* These famous liners have an average speed of 25 knots, Length, 790 ft., Breadth, 88 ft., Depth, 80ft.. Displacement on load draught, 45,000 tons, Horse Power of Turbine Engines, 68,000, Passenger accommodation, 2,300, Crew 800 to 900.

*Note.—The "Lusitania" was torpedoed and sunk by a German Submarine off the Irish Coast on May 7th, 1915.

— CLUTCHES. —

(199) Sketch two types of three-claw clutches, (1) with straight teeth, (2) with inclined teeth.



The right hand part of the clutch is securely keyed to its shaft. The left hand part is free to slide on a feather key and may be brought into mesh with the other part by means of a lever and pin working in the grooved collar.

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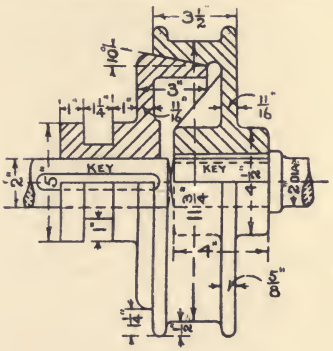
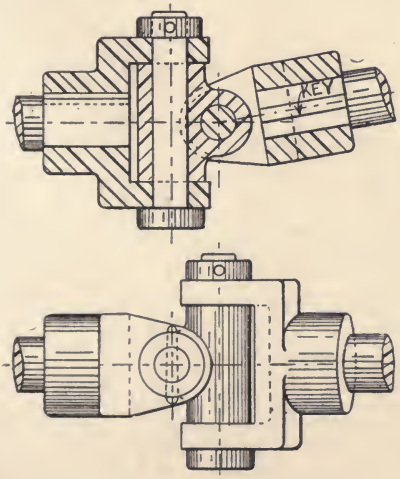
(201) Sketch a conical friction clutch. Draw out in detail a clutch for 2″ diameter shafts and a pulley $11\frac{3}{4}$″ diameter. Scale Half Size. The diameter at the bottom of the conical surface of the pulley is enlarged so that when wear takes place a ridge will not be formed.





(200) Make neat sketches showing "Hooke's Joint" or Universal Coupling and explain its object.

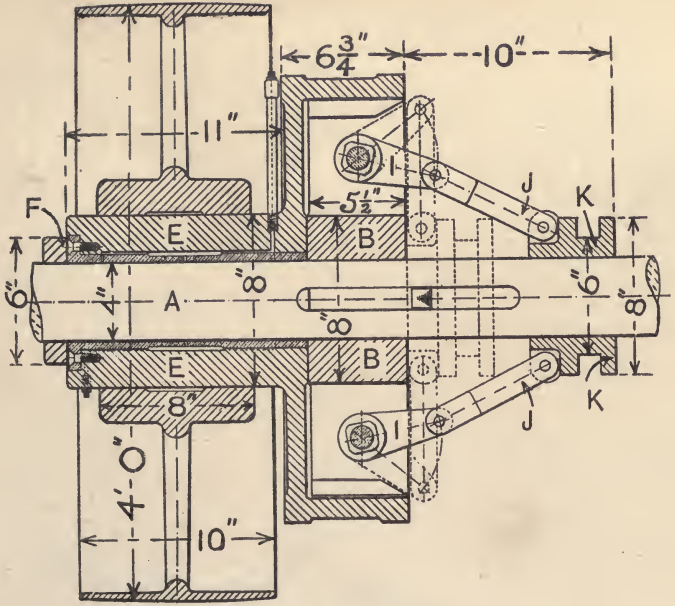
This form of coupling is used for connecting two shafts whose axes intersect.

It has the advantage that the angle between the Shafts may be varied while they are in motion.

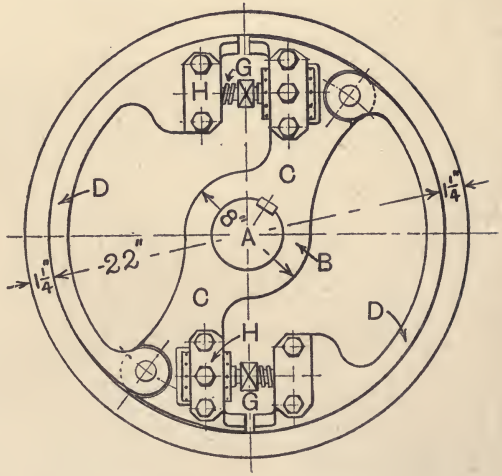
All the parts are usually made of Wrought Iron or Steel.

FRICTION CLUTCH.

HEYWOOD AND BRIDGE'S PATENT



SECTIONAL ELEVATION



FRONT VIEW OF CLUTCH

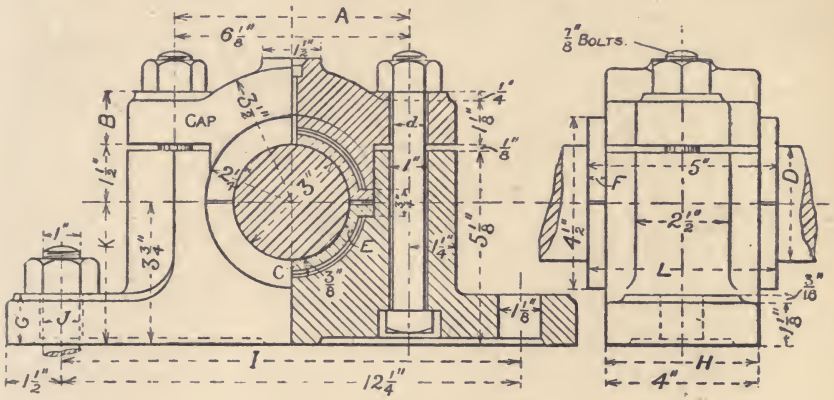
With Sliding Sleeve and Driving Pulley omitted.

The sectional elevation shows the friction wheel or internal part of clutch, and its relative position with a shell or external part. A is a shaft or prime mover, on which is keyed boss B, from the boss B are two arms C, and the rim D is fixed upon same forming the internal part of clutch. The external part or shell is made of one casting turned all over and prepared for receiving on its boss E either belt, rope pulley or wheel. This shell is kept in position on the shaft by the internal part at the shell end, and by a loose collar F at the boss end. The external part of the clutch is always bushed with gun metal and well arranged for lubrication. The internal part is expanded by means of right and left hand screws G, which work in gun-metal nuts kept in position by caps HH. On these screws are keyed levers I, which are moved backwards and forwards as shown by dotted lines by connecting links J and sliding sleeve K. The sleeve of the clutch being in position indicated by full lines when the clutch is out of gear, the dotted lines show the position of the sleeve when the clutch is in gear.

Supplied by Messrs. DAVID BRIDGE & Co., Ltd., Castleton Ironworks, CASTLETON, Manchester.

BEARINGS, PEDESTALS, HANGERS, ETC.

(49) Make neat sketches showing the construction of an ordinary Pedestal or Plummer Block suitable for a 3" Shaft, and explain how the Brasses are adjusted when they become worn. Draw an elevation, plan and end elevation, half in section, of a pedestal for a $2\frac{1}{2}$" shaft. Scale Full Size.



PROPORTIONS.

D	= dia. of Shaft.	d	= dia. of cap bolts = $\frac{1}{4}$ D + $\frac{1}{8}$"
A	= 1·6D + 1·5"	H	= ·8L
B	= 1·3d to 1·5d	I	= $2\frac{3}{4}$D + 4"
C	= ·08 D + $\frac{1}{8}$"	J	= d + $\frac{1}{8}$"
E	= about $\frac{3}{4}$C	K	= 1·1D + ·5"
F	= $\frac{3}{8}$" to $\frac{3}{4}$"	L	= from 1·5 to 2D for ordinary speeds, from 3 to 5D for high speeds.
G	= ·3D to ·4D		

WHEN THE BRASSES BECOME WORN THEY ARE ADJUSTED BY MEANS OF THE CAP AND BOLTS. IF FURTHER ADJUSTMENT IS NECESSARY THEY ARE TAKEN OUT AND FILED ON THEIR EDGES.

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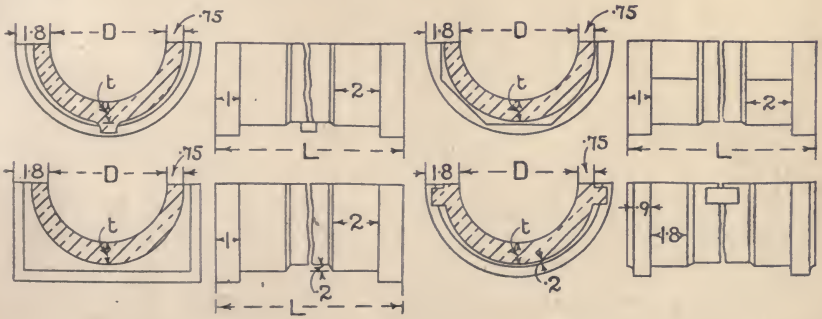
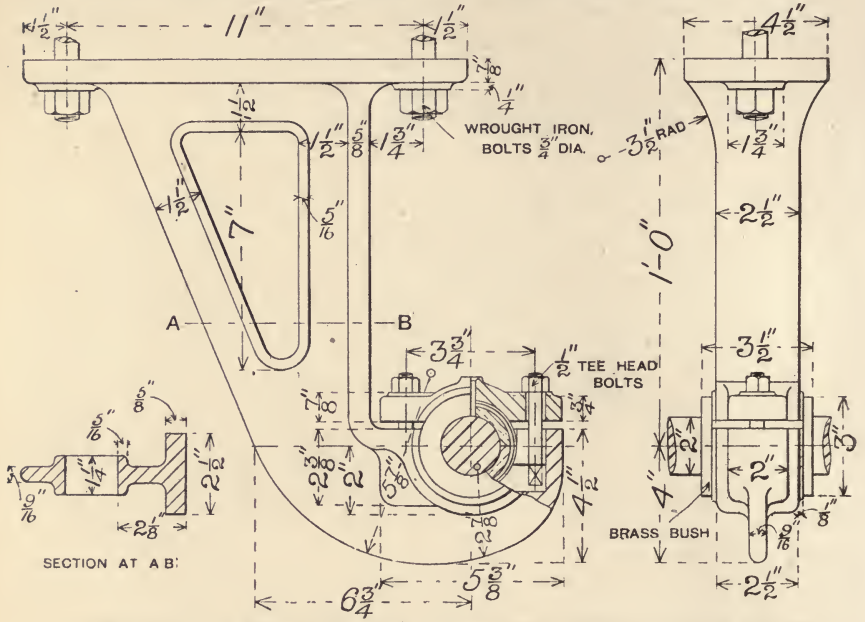
(50) *Sketch the Brasses for a Bearing, and show how they are prevented from turning in the pedestal.



— "J" HANGER. —

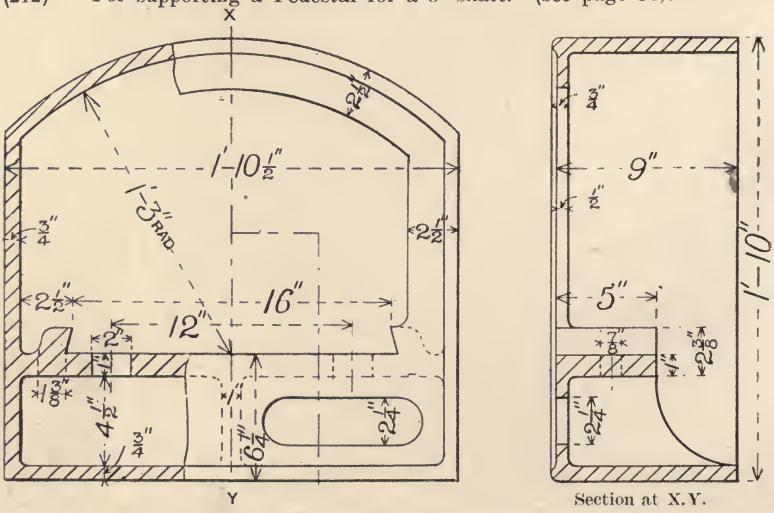
(51) This type of hanging bracket is used for supporting shafting from a roof.



Draw this Bracket, scale ¾ size, and complete the sectional plan through the line A.B. showing the cap and bolts.

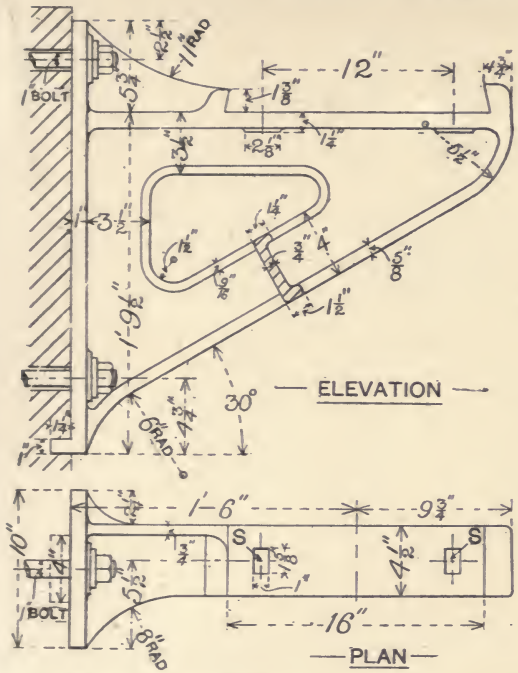
— WALL BOX. —

(212) For supporting a Pedestal for a 3″ shaft. (see page 31).



Draw this example, scale half size, and add a sectional plan.

(55) — WALL BRACKET. —

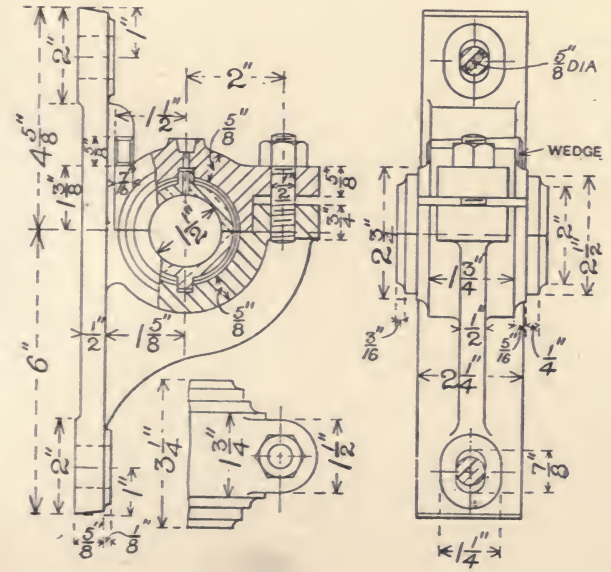


This design of Bracket is suitable for supporting a 3" horizontal shaft in a pedestal at some distance from a wall and parallel to it. Slot holes, S.S., are provided to allow for the adjustment of the Pedestal.

NOTE.—It would be good practice for a student to draw this example with the pedestal in its proper working position, and to add an end elevation.

Scale 3" = 1 foot.

(55) — PILLAR BRACKET. —

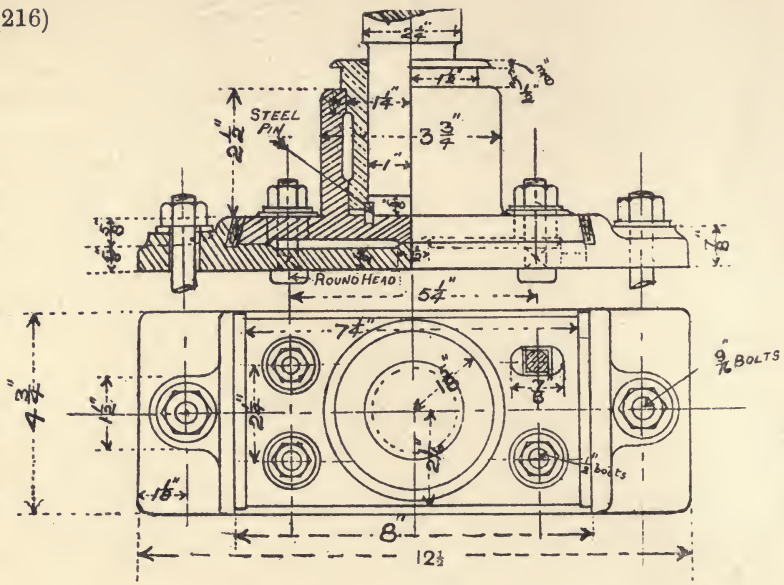


This Bracket has a short overhang, and is used for supporting a 1½" horizontal shaft from a pillar or column where there is no wall in the way of the wheels or pulleys on the shaft.

Draw this bracket full size, and add a plan view.

FOOTSTEP BEARING.

(216)

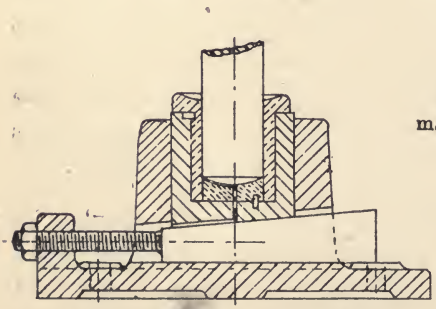


The footstep bearing shown above is used for supporting a vertical shaft. The shaft revolves in a brass bush and upon a steel disc, the bush being hollowed out at the top to facilitate lubrication. The main casting is secured to a baseplate by four bolts and hardwood wedges.

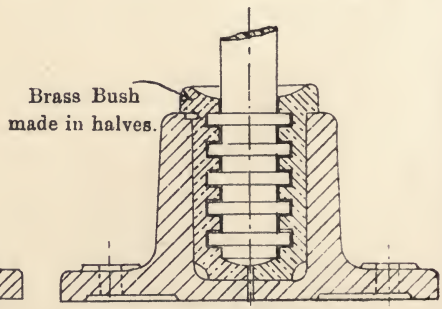
Suitable "chipping strips" are provided on the underside of the casting, as well as on the top of the base plate, and adjustment is obtained by means of slot holes.

See Page 65 for Diagrams of Journal, Pivot and Collar Bearings.

Show by sketches (1) how adjustment is provided for in a Footstep or Pivot Bearing for supporting a Vertical Spindle or Shaft. (2) Also show the ordinary form of Vertical Thrust Bearing.



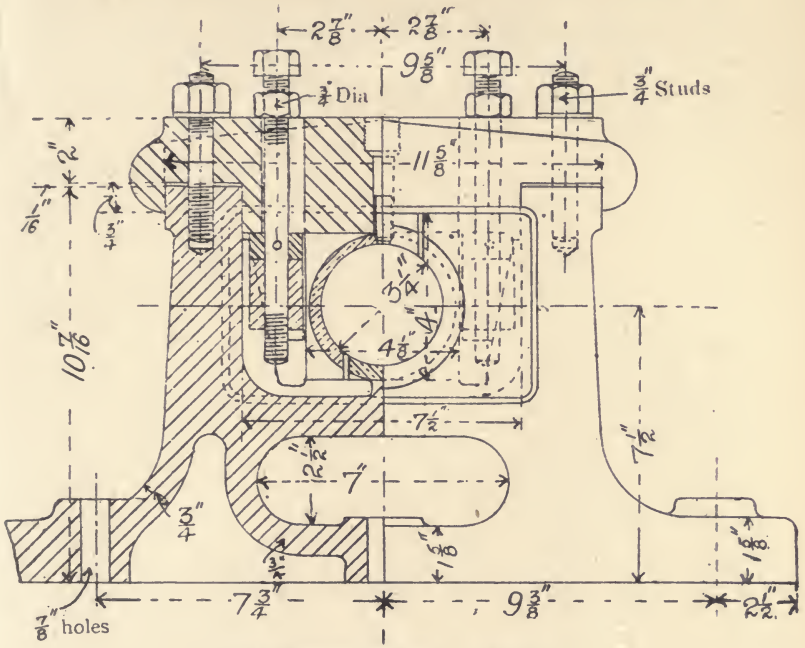
ADJUSTABLE BEARING.



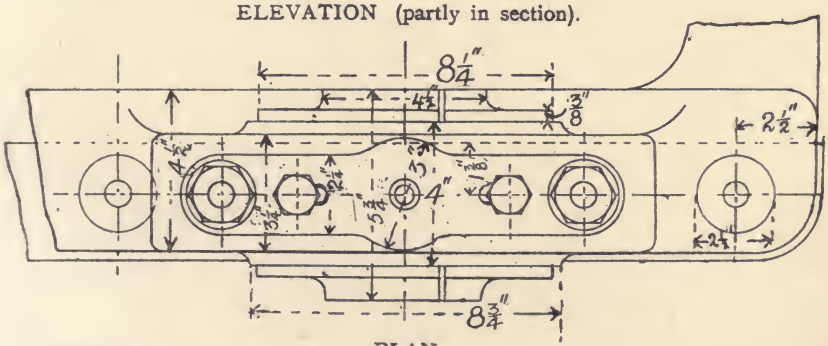
THRUST BEARING.

— DETAILS OF CRANK-SHAFT BEARING. —

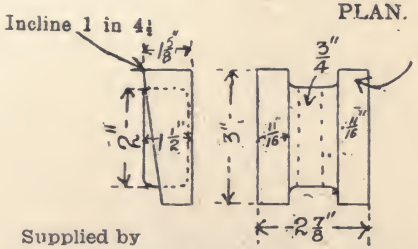
FOR 8 H.P. COMPOUND UNDERNEATH TYPE ENGINE.



ELEVATION (partly in section).



PLAN.



DETAIL OF WEDGES

The Brasses in this Bearing have both vertical and horizontal adjustment by means of the bolts and wedges.

Supplied by

Messrs. MARSHALL, SONS & CO., Limited,

Britannia Iron Works, GAINSBOROUGH.

— BALL BEARINGS. —

Ball Bearings now play a very important part in modern machine construction. They are extensively used for taking both the journal bearing load and the end thrust in both directions. Bearings of this type, when well designed, reduce friction to a minimum. The balls and ball races are made of steel, and the makers guarantee the diameter of the balls to the 10,000th part of an inch.

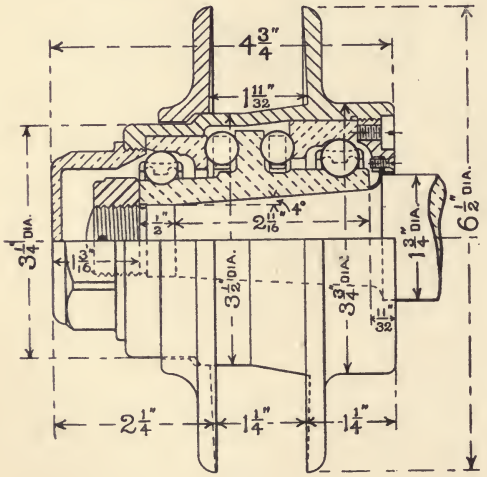


Fig. 1.

Fig. 1. shows Hoffmann's Patent Ball Bearing Hub, as applied to a motor car wheel. There are four rows of balls, ten in each row. The outer rows taking the Journal bearing load, and the two inner rows the end thrust in both directions, so that the four rows combined are capable of carrying any load that may come upon the bearing, including any canting action due to wheels or strains from cranks, etc. The balls are held in retaining cages and will not fall out. A leather dust washer is provided to exclude the dust. The balls are all $\frac{7}{16}$" diameter, except the outer right hand row, these being $\frac{1}{2}$" diameter.

Fig. 2. shows Hoffmann's Patent Double Compound Bearing, as applied to a marine thrust block. In this example there are four rows of balls, the two outer rows taking the journal bearing load, and the two inner rows the end thrust in both directions, so that the four rows combined are capable of carrying any load that may come upon the bearing.

There are twelve balls in each row, $\frac{9}{16}$" diameter.

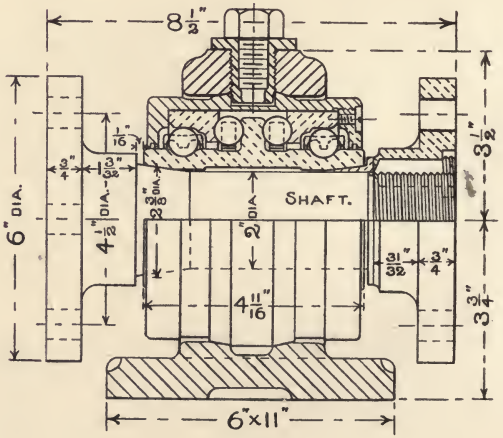


Fig. 2.

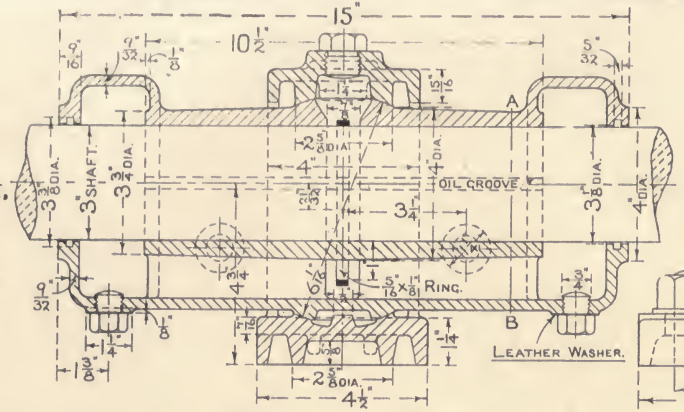
Supplied by

MESSRS. THE HOFFMANN MANUFACTURING CO., LTD.,

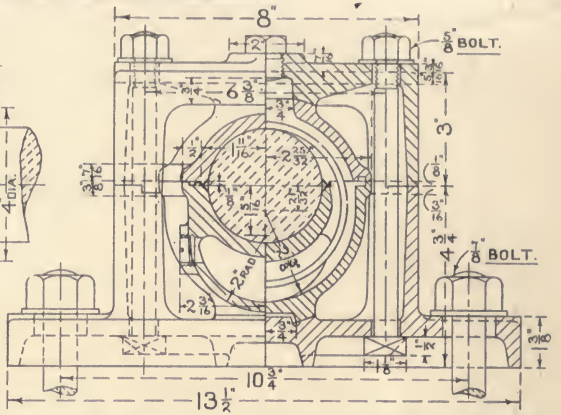
CHELMSFORD, Essex.

— 3" RING OILED SWIVELLING BEARING AND PEDESTAL. —

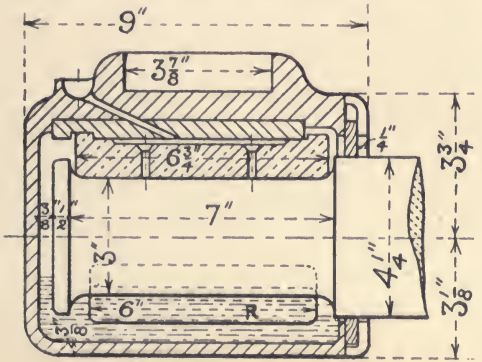
Supplied by
Messrs. KYNOCH,
Limited,
Lion Works,
BIRMINGHAM.

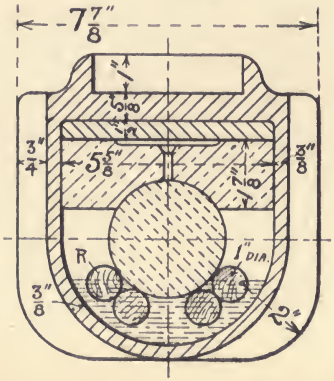


SECTIONAL ELEVATION.



SECTION AT A.B SECTION THROUGH CENTRE.





— OIL BATH BEARING. —

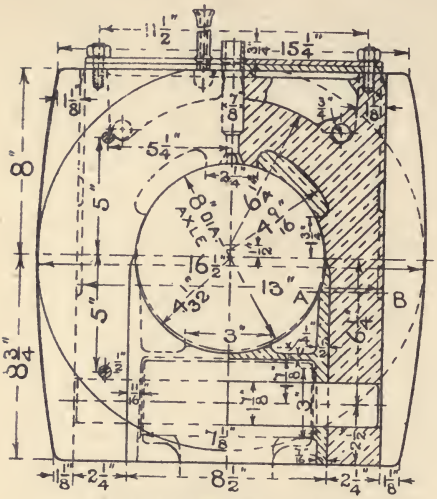
FOR LOCOMOTIVE CRANES AND RAILWAY AXLES.

R.R. 1" Dia. Wooden Floating Rollers.

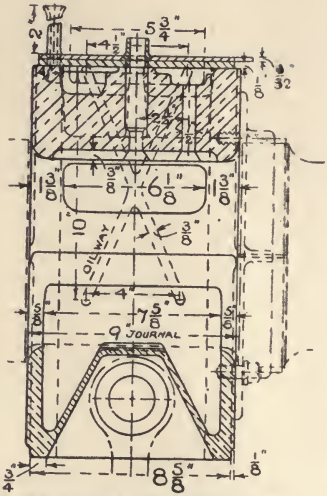
Designed and Supplied by
Mr. STEPHEN H. TERRY, M.Inst.C.E., M.I.M.E.,
Consulting Engineer,
Westminster, S.W.

— DETAILS OF AXLE BOX. —

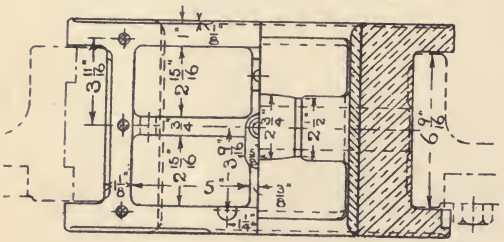
USED ON THE GLASGOW AND SOUTH WESTERN RAILWAY EXPRESS LOCOMOTIVES



— ELEVATION (HALF IN SECTION.) —



— SECTIONAL ELEVATION. —



— PLAN (COVER OFF). — SECTION AT A.B. —

— MATERIALS. —

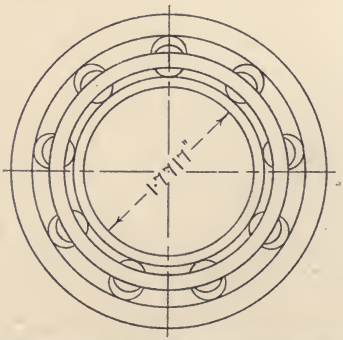
Axle Box	... ...	Bronze.
Sponge Box	... ...	Brass.
Cover	... ...	Steel.
Oil Pipes	... ...	Copper.

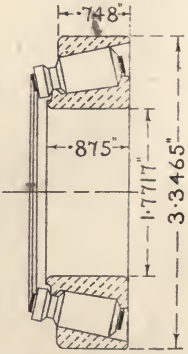
— Supplied by —

THE NORTH BRITISH LOCOMOTIVE CO., LTD.,
GLASGOW.

"TIMKEN" PATENT ROLLER BEARING.

Used on the front and rear axles of automobiles. The size of bearing shown is used for loads up to 675 lbs. at speeds not exceeding 500 revs. per min.



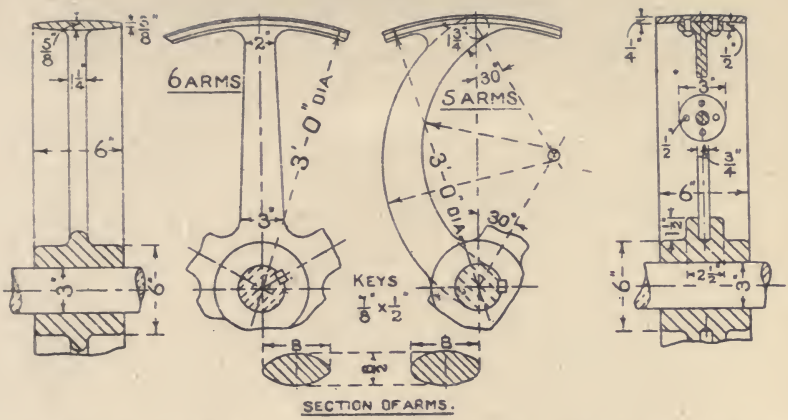


Supplied by

THE ELECTRIC AND ORDNANCE ACCESSORIES CO., Limited, ASTON, BIRMINGHAM.

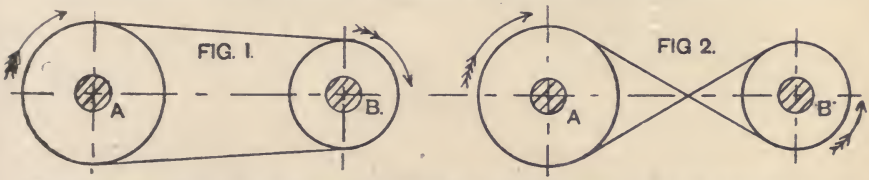
(70)

BELT PULLEYS.



Curved arms are less liable to fracture from contraction in cooling than the straight ones. The rim is curved to prevent the belt working off the pulley and the centre of the rim is known as the "crown." Flanges are sometimes employed for the same purpose. When the belt has to be moved from one part of the width of a pulley to another, the outside of the rim section should be straight. The right hand example shows a part section of the patent "Stanchion" wrought iron pulley made by Messrs. Douglas, Lawson & Co., Birstall, Nr. Leeds.

Motion is transmitted between two shafts by means of belts passing over pulleys as shown in Figs. 1 and 2. The belt may be an open belt, Fig. 1, or a crossed belt, Fig. 2. In the former case the two shafts rotate in the same direction. In the latter they rotate in opposite directions. *(see arrows).*



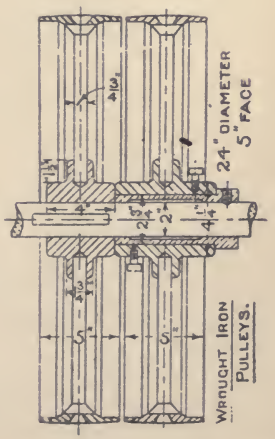
The proportion between the revolutions of the shafts **A** and **B** depends upon the diameters of the pulleys keyed upon them and is in the inverse ratio of those diameters.

Speed of Belt Pulleys.

Simple Rule for ascertaining the speed of shafts, and calculating the size of pulleys required to give a definite speed.

RULE.—Multiply those two numbers together which belong to the same pulley, and divide by the third number, and the result is the answer required.

(73)



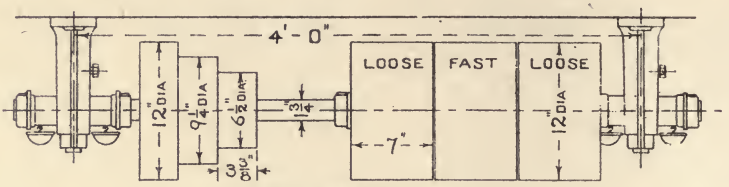
Section of Wrought Iron Fast and Loose Pulleys.

By Messrs. Croft & Perkins, Bradford.

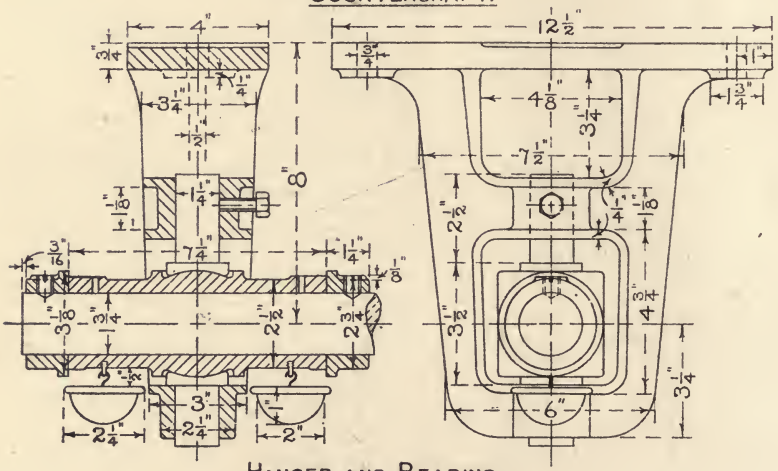
The method of connecting the arms and rims should be noted. A brass bush is inserted in the boss of the loose pulley, and the boss is extended considerably to obtain a good large bearing surface. Two oil cups are also placed in the boss.

— TWO SPEED COUNTERSHAFT. —

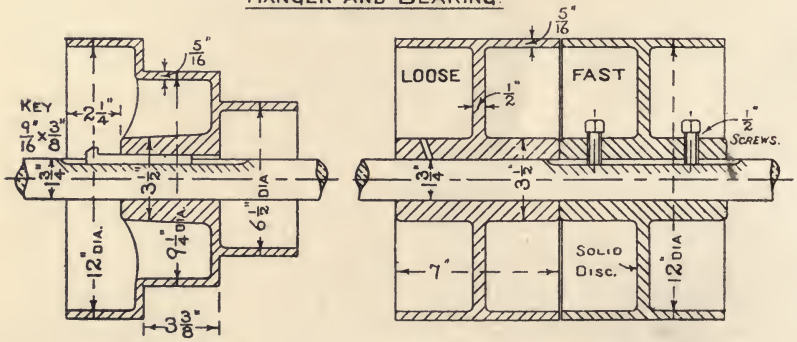
FOR 8½" CENTRE LATHE. SPEEDS, 288 AND 223 REVS. PER MIN.



COUNTERSHAFT.



HANGER AND BEARING.



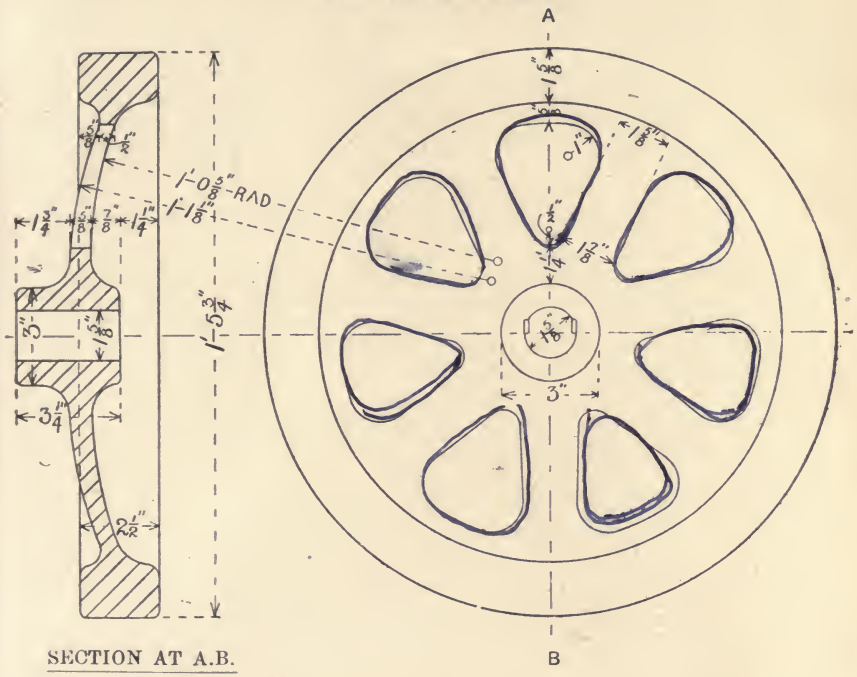
3 SPEED CONE

FAST AND LOOSE PULLEYS

The bearings for supporting the countershaft are of the adjustable swivelling type. The fast pulley is secured to the shaft by means of two screws instead of a key. The belt shipping gear is not shown.

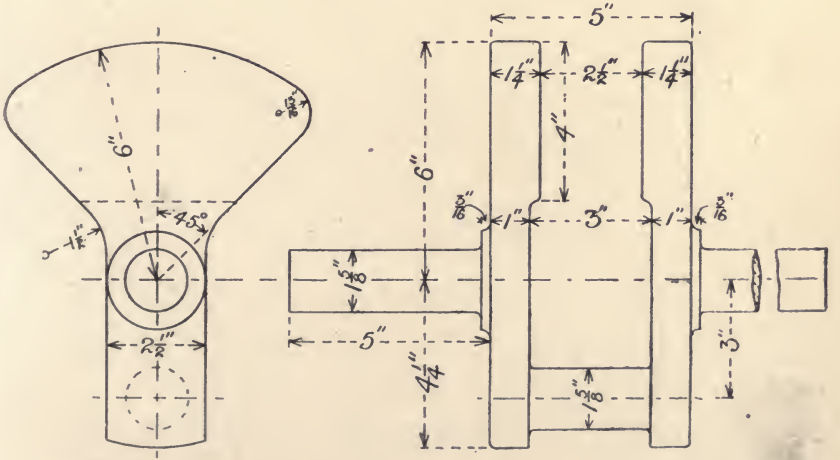
Supplied by
Messrs. C. REDMAN & SONS,
Pioneer Ironworks, HALIFAX.

— FLY-WHEEL AND CRANK —
OF
HOLROYD SMITH'S PATENT OIL ENGINE
— FOR MOTOR CARS. —



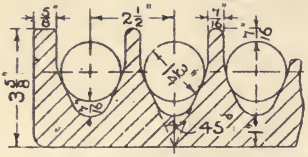
SECTION AT A.B.

61



Supplied by
Mr. M. HOLROYD SMITH, M.I.M.E., M.I.E.E.,
Consulting Engineer, Westminster, S.W.

(75) — ROPE PULLEYS. —



PART SECTION OF ROPE PULLEY RIM.

SECTION OF WIRE ROPE PULLEY RIM.

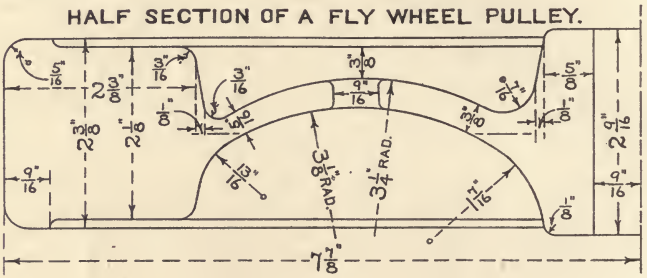
Hemp and Cotton ropes are largely employed for driving in mills.

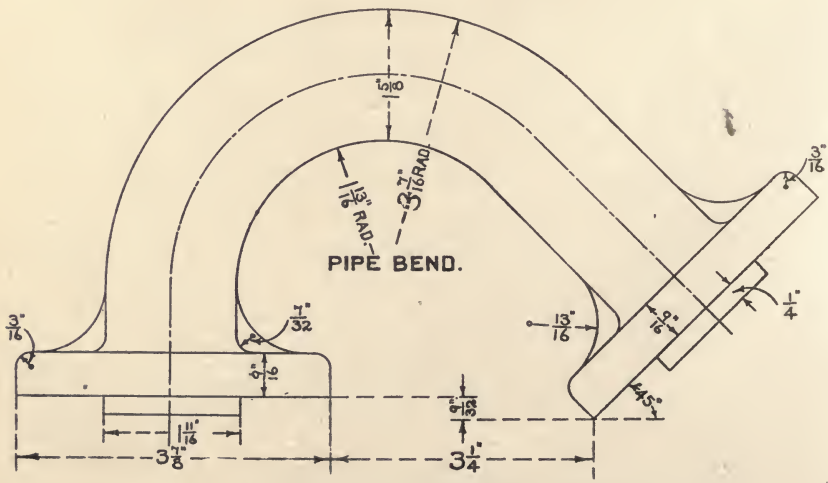
Wire ropes are used in collieries, mines and for haulage and lifting purposes generally.

EXAMPLES TO BE TRACED.

The two examples given below have been taken from recent Board of Education Examination Papers in "Machine Construction and Drawing." The dimensions have however been added, so that a student may set out for himself, full size, the "copy" as given in the test paper, and then proceed to make an ink tracing. Indian ink must be used, which should be quite black, and the lines of the tracing should be uniform and of moderate width. Ink in the curves first.

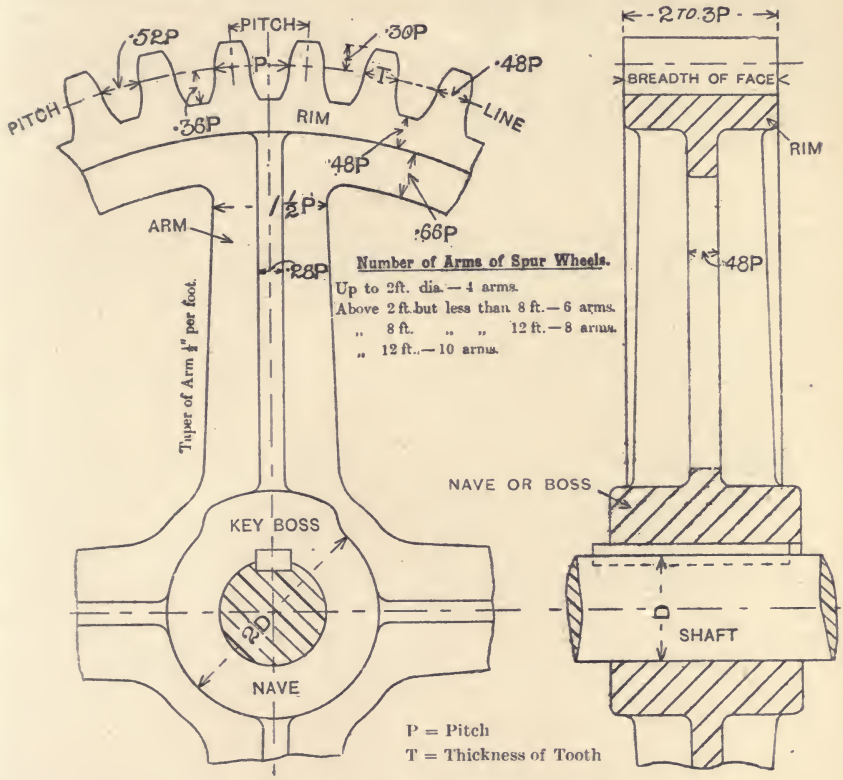
HALF SECTION OF A FLY WHEEL PULLEY.





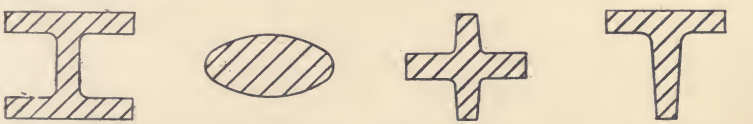
TOOTHED GEARING.

What is the meaning of the terms Pitch *(Circular)*, Breadth of Face, Thickness of Tooth, Pitch Line, Rim, Nave and Arm as applied
(59) to toothed gearing?



$$\text{Circular Pitch} = \frac{3{\cdot}14 \times \text{Dia. of Pitch Circle.}}{\text{No. of teeth.}} \qquad \text{Diametral Pitch} = \frac{\text{No. of teeth.}}{\text{Dia. of Pitch Circle.}}$$

(223) **SECTIONS OF ARMS FOR WHEELS.**

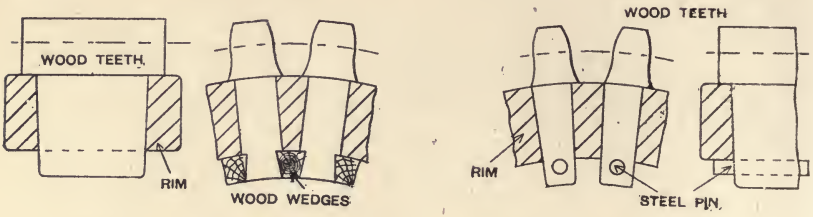


What is the object of "shrouding" wheel teeth?

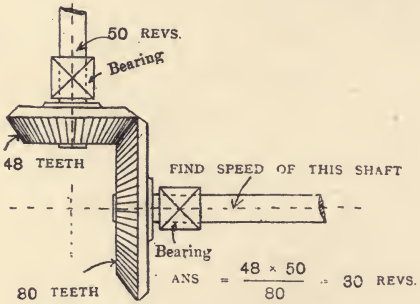
SECTIONS OF SHROUDED WHEEL TEETH.

THE OBJECT OF SHROUDING IS TO ADD TO THE STRENGTH OF THE TEETH, AND THE ADVANTAGE IS GREATER THE NARROWER THE WHEEL.

Make a neat sketch of a Mortice Spur Wheel, and show how the teeth are secured to the Rim.
(64)



A Shaft running at 50 revolutions per minute, has on a Bevel Wheel with 48 teeth, gearing into another Wheel with 80 teeth.
(66) Find the speed of the second Shaft. *(See sketch.)*

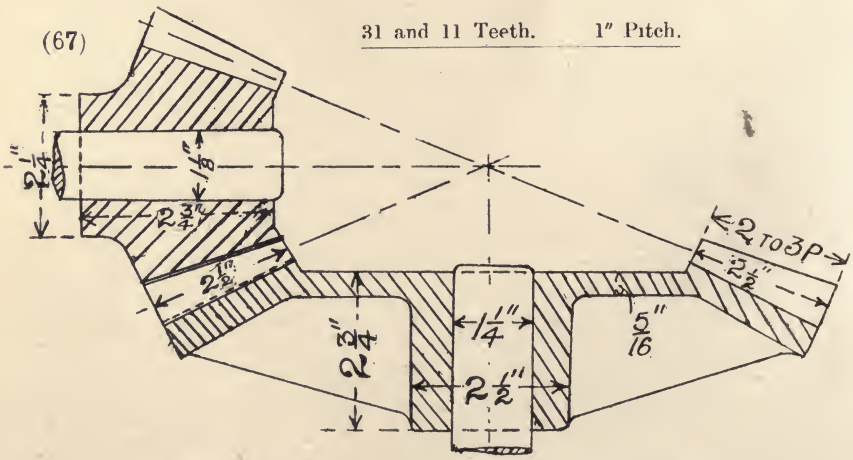


SIMPLE RULE.

Multiply those two numbers together which belong to the same wheel, and divide by the third number, and the result is the answer required.

Show the construction of a pair of Bevel Wheels in section.

(67) 31 and 11 Teeth. 1″ Pitch.



Draw this Example full size and add an Elevation and Plan.

BUILT-UP WHEEL DETAILS.

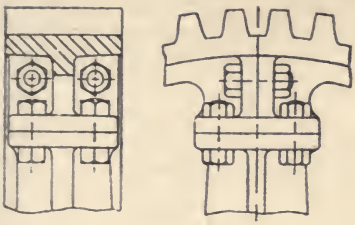


Fig. 1.

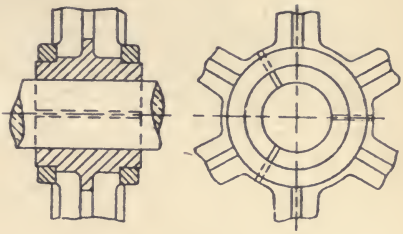
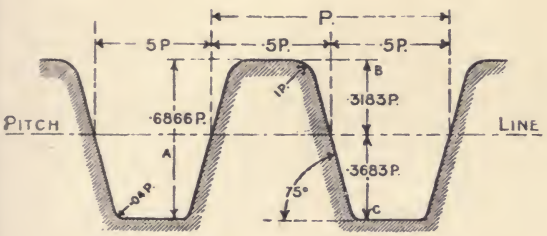


Fig. 2.

In order to facilitate handling and transit, large wheels are usually "built up." Fig. 1 shows an arm and rim fastening, where the rim joint comes in the centre line of the arm. If the boss is made separate from the arms, they may be secured by bolts or turned and cottered into the boss. If the joint in the rim segments comes in between the arms, the segments are provided with flanges at the ends, as well as in the centre for the arm fastening. Fig. 2 shows the split boss of a large wheel. The boss is split, as it is difficult to obtain a sound casting otherwise, due to the unequal contraction of the metal. Two wrought iron rings or hoops are shrunk on to the turned part of the boss.



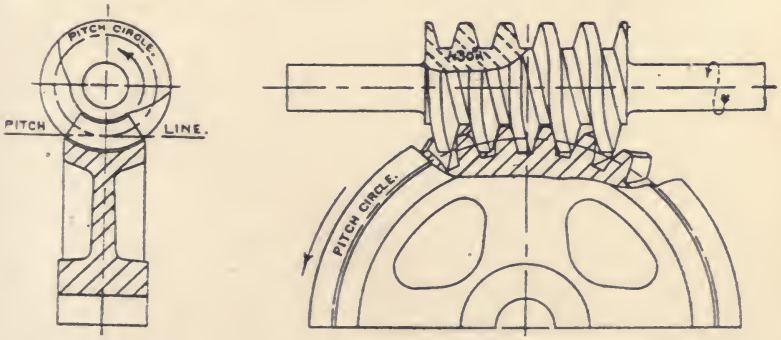
SECTION OF WORM THREAD.

The thread is cut at an angle of 75°, with straight sides, and the corners slightly rounded. The diagram shows the proportions, P = Pitch.

The outside diameter of a worm wheel of over 30 teeth equals

$$\text{No. of teeth} + 2 \times \text{Pitch}.$$

3·1416.



RIGHT HAND SINGLE THREAD WORM GEAR.

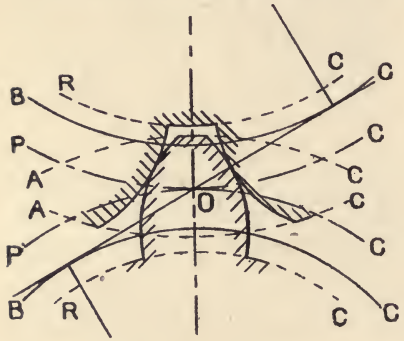
Supplied by Messrs. D. BROWN & SONS, (Hfd.,) Ltd., Lockwood, HUDDERSFIELD.

HELICAL GEARS. The teeth of double helical wheels form a broad V, 70° angle. They are stronger and more silent when running than spur wheel teeth.

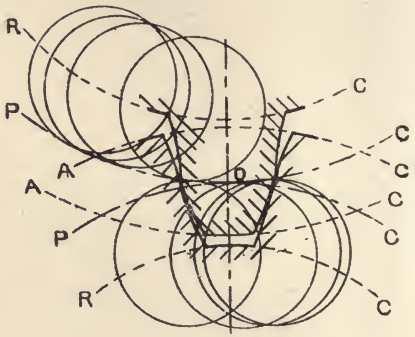
SCREW OR SPIRAL GEARS are used when the axes for transmitting motion are not in the same plane, the threads being cut spiral.

— PROFILES OF SPUR WHEEL TEETH. —

Two gear wheels will work correctly together, that is, they will produce the same velocity ratio at any instant as two non-slipping rollers working together, (whose diameters equal the pitch circle diameters of the gears), if a line at right angles to the curves at their point of contact passes through the pitch point. *Involute* and *Cycloidal* curves both satisfy this condition. The former is produced by rolling a straight line about a circle, and the latter by rolling a circle about a straight line or circle.



INVOLUTE TOOTH.



CYCLOIDAL TOOTH.

INVOLUTE TOOTH.—To draw an Involute tooth, set out first the pitch circles of the two wheels, P.C., O, is the pitch point. Draw the addendum and root circles, A. C. and R. C., and mark out the width of a tooth, half on each side of the pitch point, (see proportions, page 43.) Draw a line to pass through the pitch point at an angle of 15° to the horizontal, and the base circles, B.C., which just touch this line, should be drawn from the wheel centres. *Note.—The angle is enlarged in the accompanying diagram in order to show the principle of the curve more clearly.* To obtain the curve, a line should be drawn on tracing paper and worked around the lower base circle, the path of the end of the line which should pass through the point marked for the tooth width, should be marked by pencil or pin. By transferring the line to the other side of the base circle, the other side of the tooth may be drawn.

The sides of an involute rack tooth are straight at an angle of 15° to the vertical. A slight variation in the shaft centres does not effect the running of involute gears.

CYCLOIDAL TOOTH.—When the generating circles are rolled on a straight line (rack teeth) the curves are cycloidal. If rolled on the outside of a circle the curves are *epicycloidal*, if on the inside, the curves are *hypocycloidal*.

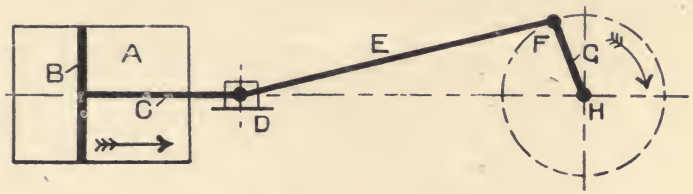
First set out the pitch circles of the two wheels, P.C., the addendum and root circles, A. C. and R. C., and mark out on the pitch line the width of the tooth (see proportions on page 43). Draw out the rolling circle on tracing paper and mark on same a point which should be made to coincide with the point marked on pitch line for the edge of the tooth. When the left hand point of the tooth is being drawn roll the circle to the right and prick through the path of the point on the generating circle until it reaches the addendum line. Roll the circle on the inside of the pitch circle in a similar way to produce the flank of the tooth. The profile on the other side may be obtained by rolling the generating circle in the opposite direction. The same rolling circles should be used for the teeth of both wheels, or if two rolling circles are used, the rolling circle used for the flanks in one wheel must be used for the points in the other.

The most suitable size of rolling circle should be half the diameter of the smallest pinion; the larger the circle the straighter and weaker become the teeth. In the case of a small pinion, if the rolling circle equals the radius of the pitch circle, the flanks of the teeth will be straight and radiate from the centre of the wheel.

For further information and tables on Gearing see the Author's books "Machine Shop Companion" and "Practical Workshop Mechanics."

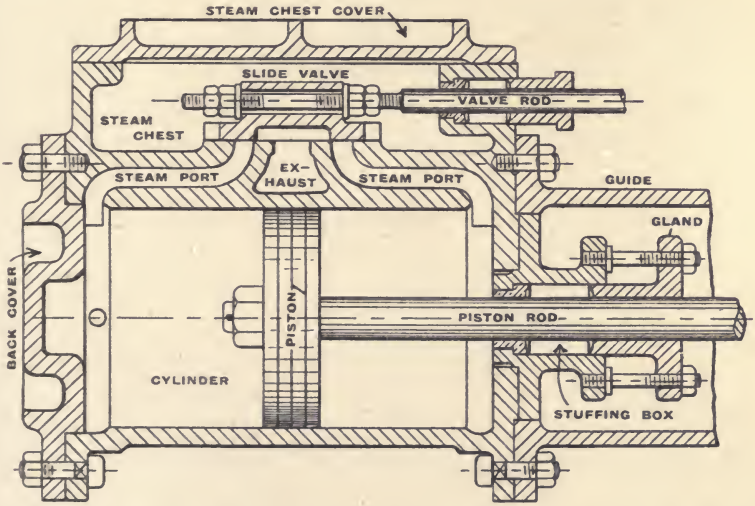
ENGINE DETAILS.

Diagrammatic sketch of the principal parts of a Steam Engine.



A. Cylinder.	E. Connecting Rod.
B. Piston.	F. Crank Pin.
C. Piston Rod.	G. Crank.
D. Crosshead.	H. Crank Shaft.

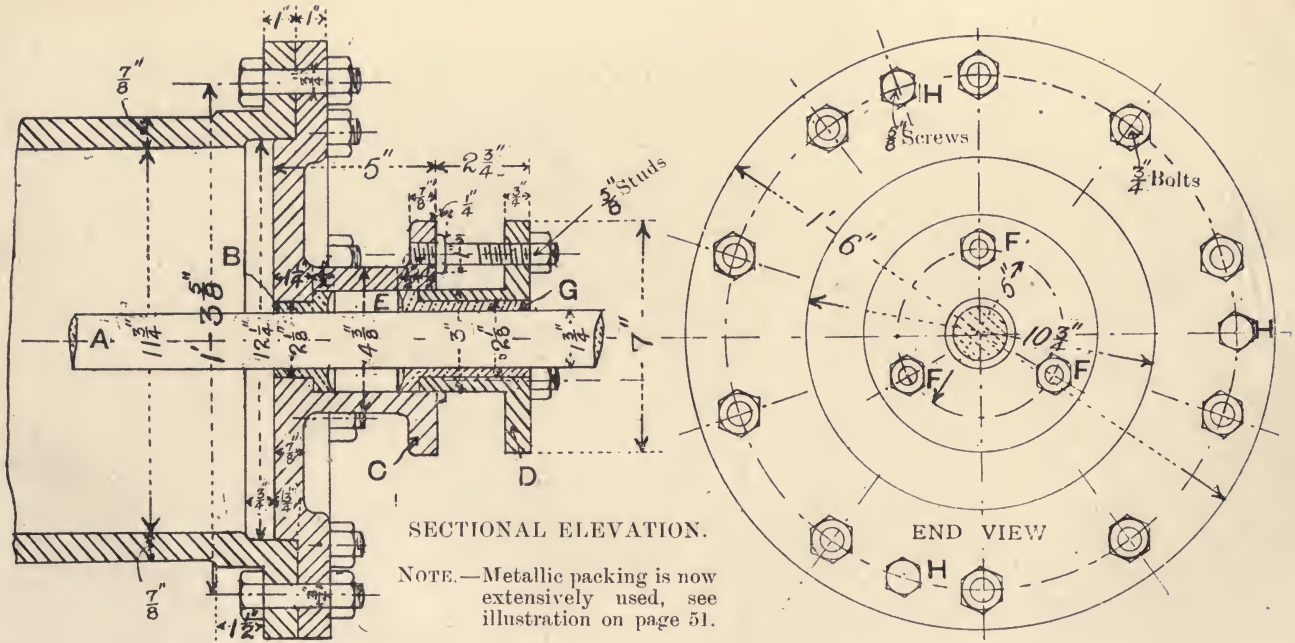
Sketch the horizontal section through a Steam Engine Cylinder, showing the piston and slide valve at mid-stroke. Name the (266) various parts and explain the method of working.



The steam from the boiler is conveyed by a pipe to the steam chest, then the slide valve, which is operated by an eccentric, opens the steam port and steam enters the cylinder, pushing the piston forward. At the position shown in sketch, the slide valve has closed the steam port and the piston completes its stroke by means of the expanding steam. Just before the piston finishes its stroke, steam is admitted through the other steam port and the piston commences its back stroke. Any steam remaining behind the piston escapes through the empty steam port to the exhaust.

To keep the piston rod and valve rod steam tight in passing through the cylinder end, each is provided with a stuffing box and gland. The stuffing box packing may be asbestos or hemp, but more up-to-date practice is to use metallic packing. See page 51.

CYLINDER COVER AND STUFFING BOX.



SECTIONAL ELEVATION.

NOTE.—Metallic packing is now extensively used, see illustration on page 51.

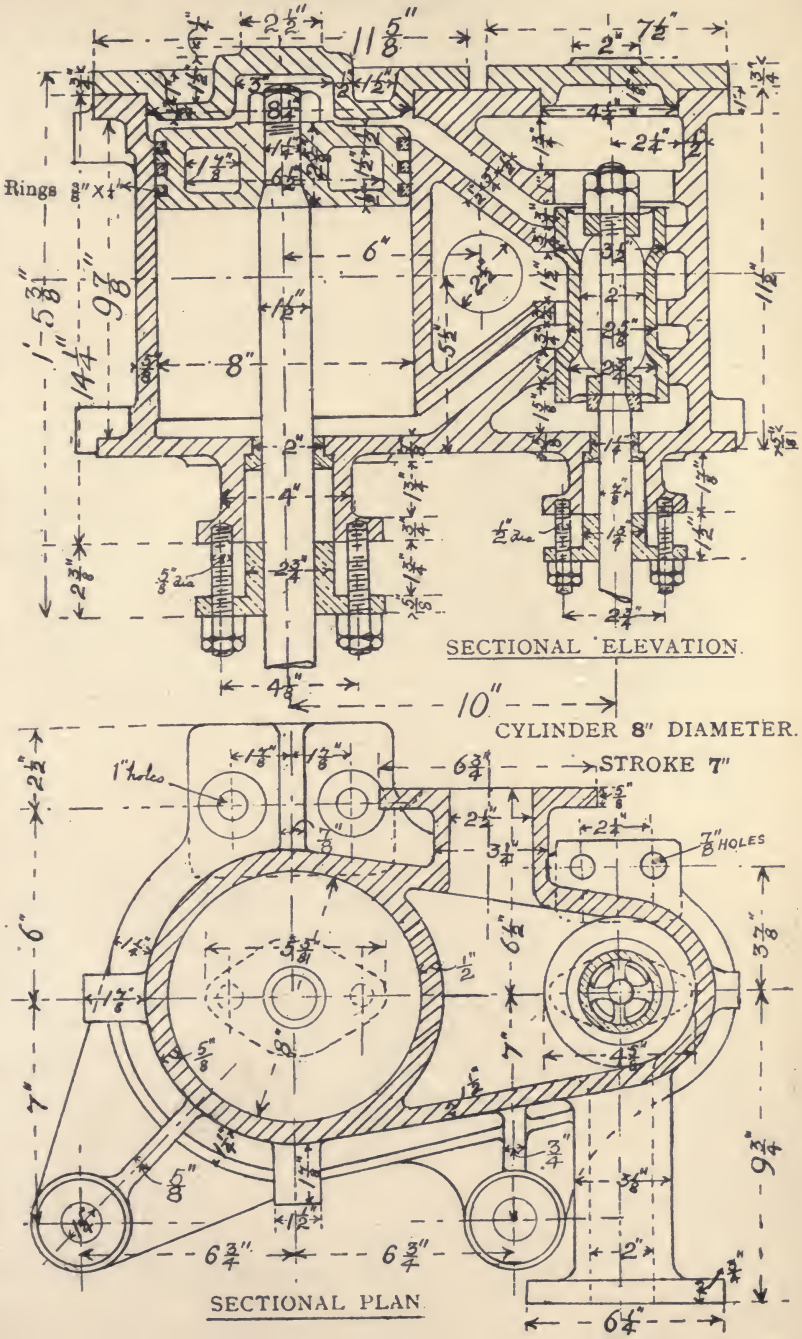
The above example shows a cylinder cover and stuffing box for a horizontal steam engine. The piston rod A, moves backward and forward through the cylinder cover, in which is fitted a brass bush B. To prevent the steam from escaping round the piston rod, a stuffing box C and gland D is provided, the latter also containing a brass bush or liner, G. The space E round the rod is filled with packing of asbestos, hemp, or other suitable material saturated with tallow, the gland D is forced up by means of the three screws and nuts F, which compresses the packing round the piston rod, and thus prevents the escape of steam. It will be noticed from the sketch, that the brass bushes B and G are recessed or hollowed out to enable the packing to be more efficiently compressed round the rod.

The cover is secured to the cylinder by means of bolts or studs, it should be noticed that the cover is hollowed out all the way round. The three set-screws, H, are screwed through the cover only, their points coming against the cylinder end, they are used for loosing the cover when the nuts have been removed from the bolts.

DETAILS OF CYLINDER & PISTON VALVE

(35) FOR HIGH SPEED VERTICAL ENGINES.

FOR ELECTRIC LIGHTING & OTHER PURPOSES. SCALE 2" = 1 FOOT.



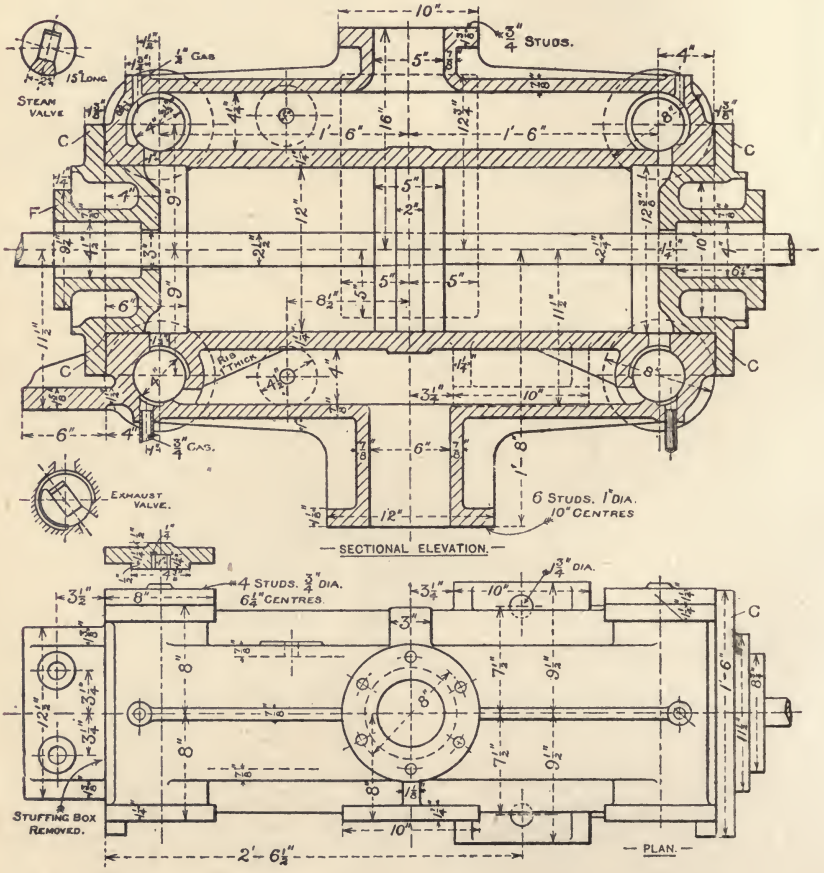
SUPPLIED BY MESSRS. ERNEST SCOTT & MOUNTAIN. LTD.,
Electrical Engineers, NEWCASTLE-ON-TYNE.

— DETAILS OF —

— HIGH-PRESSURE CYLINDER, —

— FOR —

COMPOUND TANDEM CORLISS ENGINES.



Supplied by

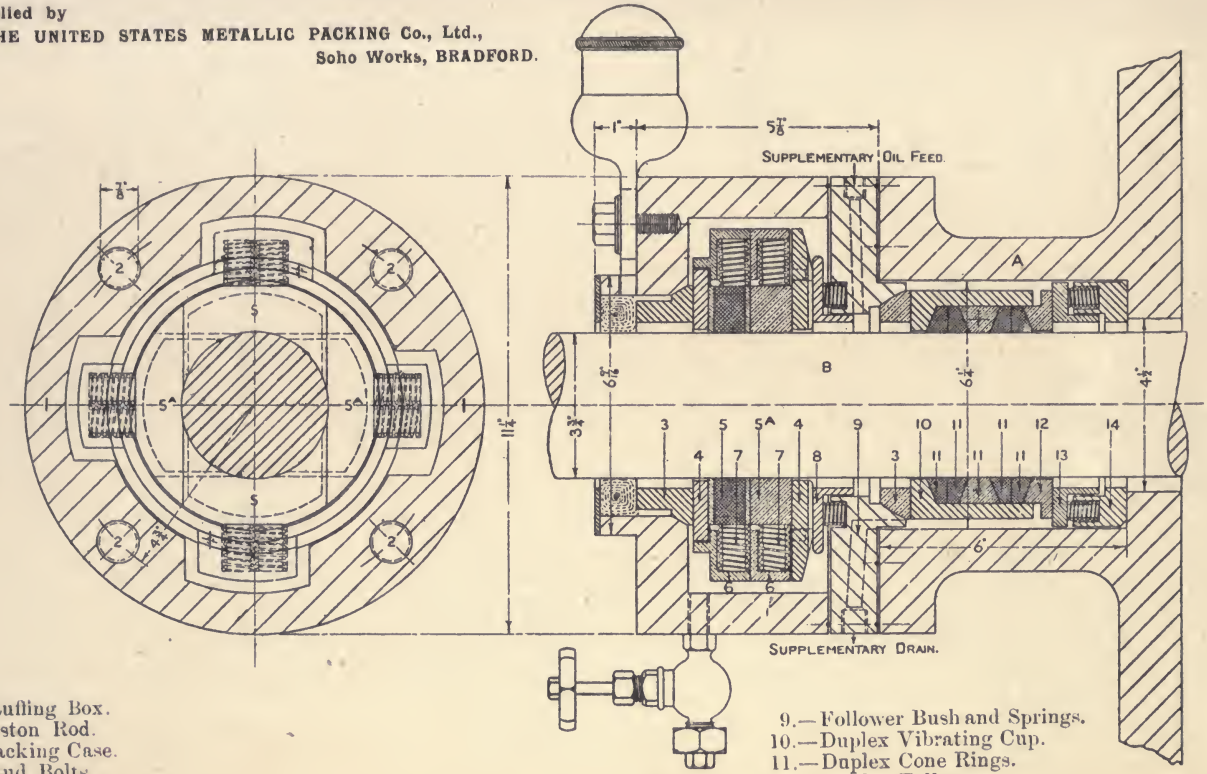
Messrs. WOOD BROTHERS,

Engineers. SOWERBY BRIDGE.

METALLIC PACKING.

HORIZONTAL DUPLEX TYPE.

Supplied by
Messrs. THE UNITED STATES METALLIC PACKING Co., Ltd.,
Soho Works, BRADFORD.

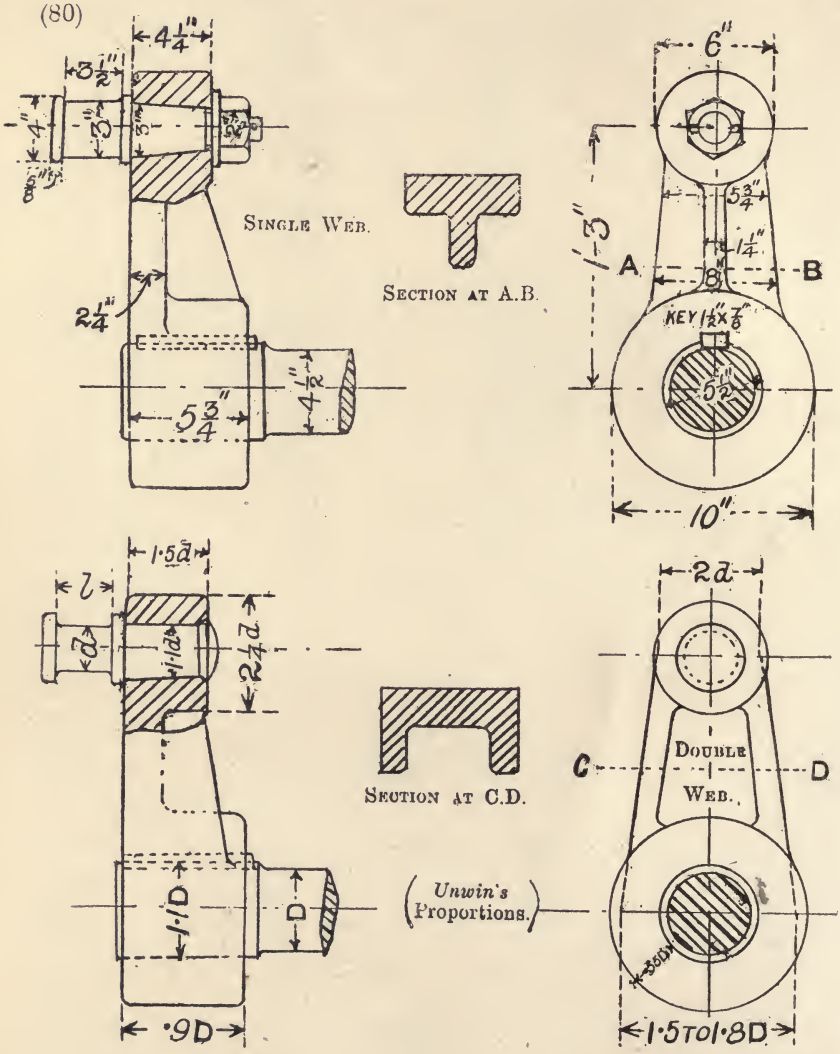


A.—Stuffing Box.
B.—Piston Rod.
1.—Packing Case.
2.—Stud Bolts.
3.—Ball Joints.
4.—Sliding Plates.
5.—Packing Blocks.
5A.—Guide Blocks.
6.—Horn Rings.
7.—Block Springs.
8.—Spring Cover Plate.
9.—Follower Bush and Springs.
10.—Duplex Vibrating Cup.
11.—Duplex Cone Rings.
12.—Duplex Follower.
13.—Duplex Spring Cover.
14.—Duplex Spring Holder.

CRANKS AND ECCENTRICS.

Show by sketches two forms of Cast Iron Cranks, one with a single "web" and one with a double "web."

(80)



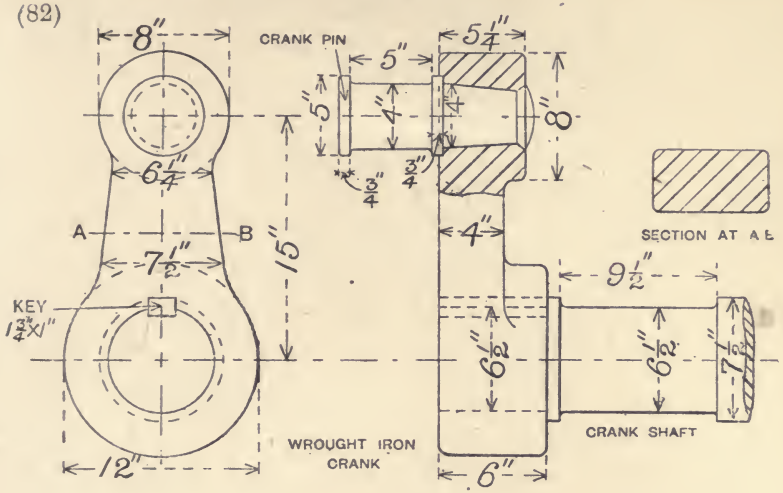
AN ENGINE CRANK is employed for converting the reciprocating motion of the piston into the circular motion of the crank-shaft.

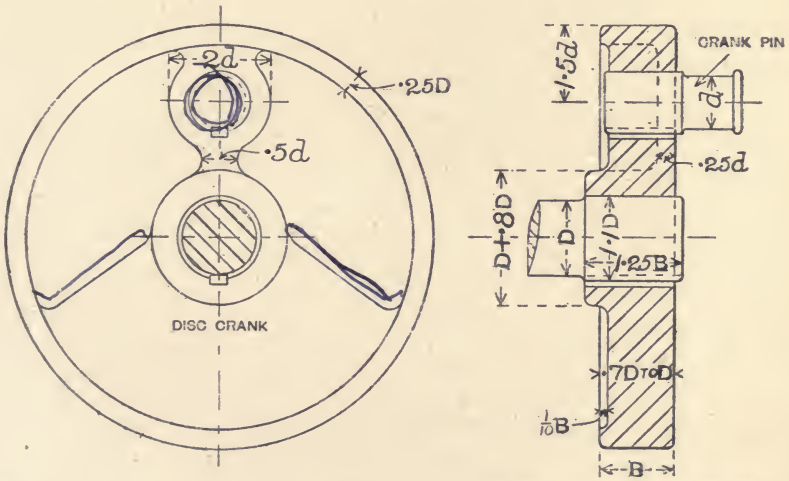
The "THROW" of a crank is equal to the diameter of the crank-pin path, and to the stroke of the piston.

CRANK-PIN. The length (l) of a crank-pin in practice varies from 1 to 1½ times the diameter. The maximum pressure upon the crank-pin should not exceed 600 lbs. per square inch (measuring area, as length × diameter), a good average is 400 lbs.

Make sketches of a Wrought Iron Crank, also of a Disc Crank, and mark on the proportions of the latter.

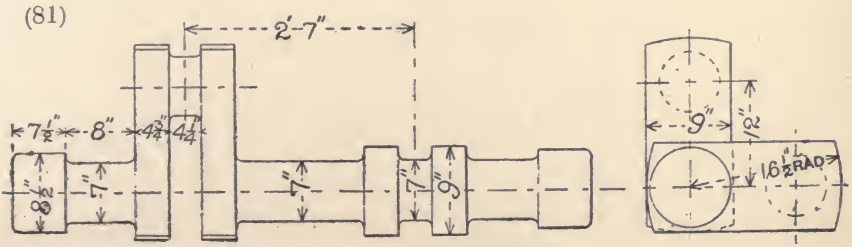
(82)





Make neat sketches showing the construction of a Locomotive Crank Shaft.

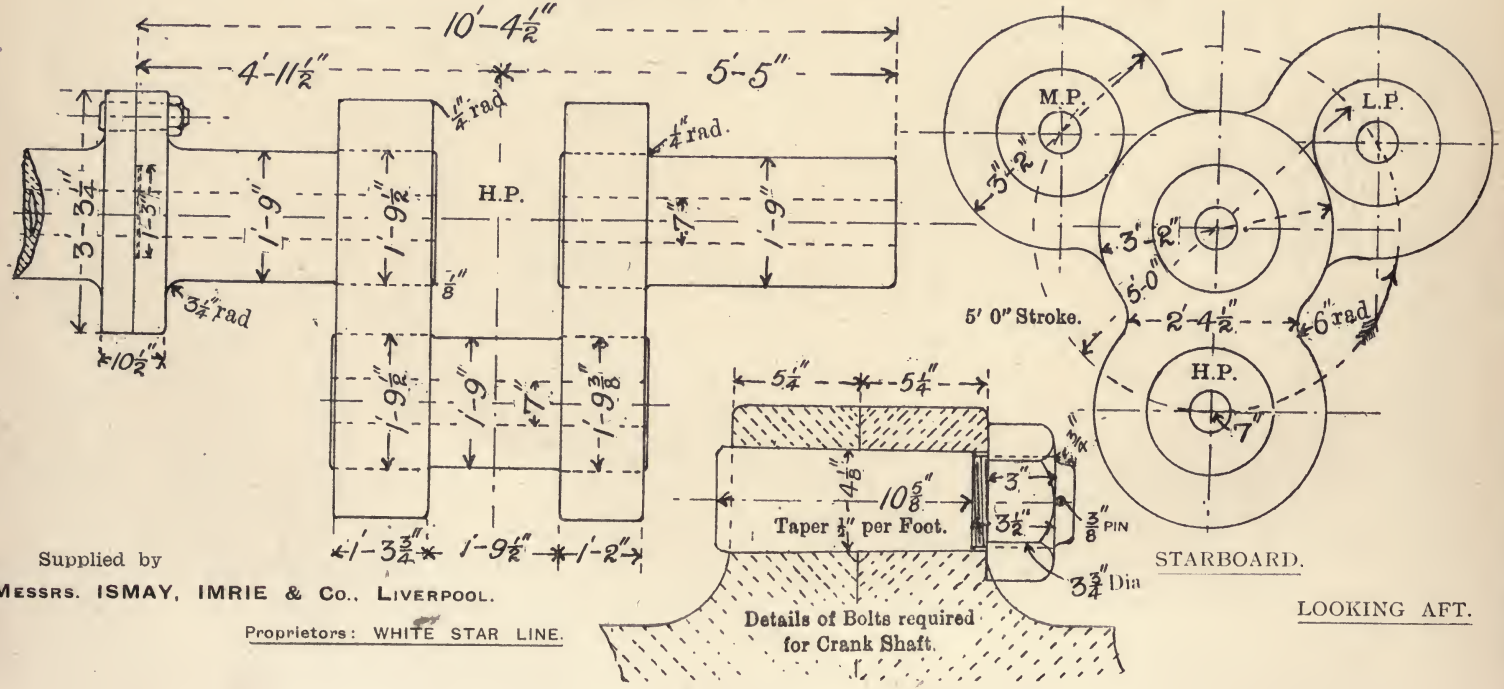
(81)



S.S. "MAJESTIC" AND "TEUTONIC."

DETAILS OF CRANK SHAFT.

Weight 12 tons 4 cwts. 3 qrs.



Supplied by

MESSRS. ISMAY, IMRIE & CO., LIVERPOOL.

Proprietors: WHITE STAR LINE.

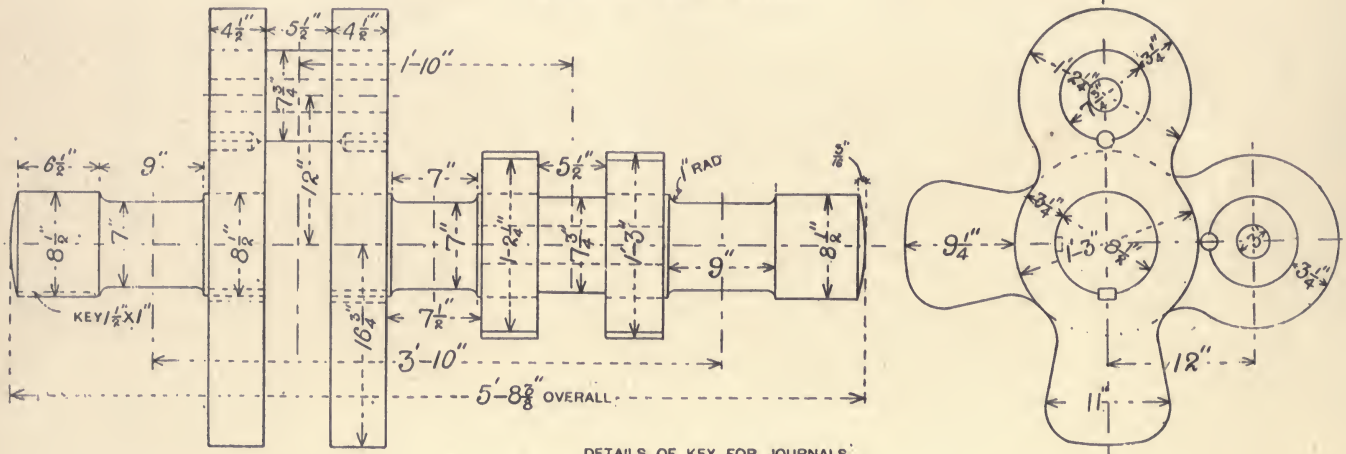
DETAILS OF CRANK AXLE.

LONDON AND NORTH WESTERN RAILWAY.

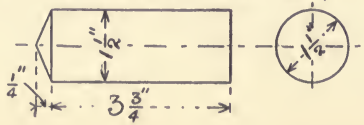
For 7' 0" Four Wheels Coupled Compound Passenger Engine.

"BLACK PRINCE."

(Mr. F. W. Webb's System.)



DETAILS OF KEY FOR JOURNALS



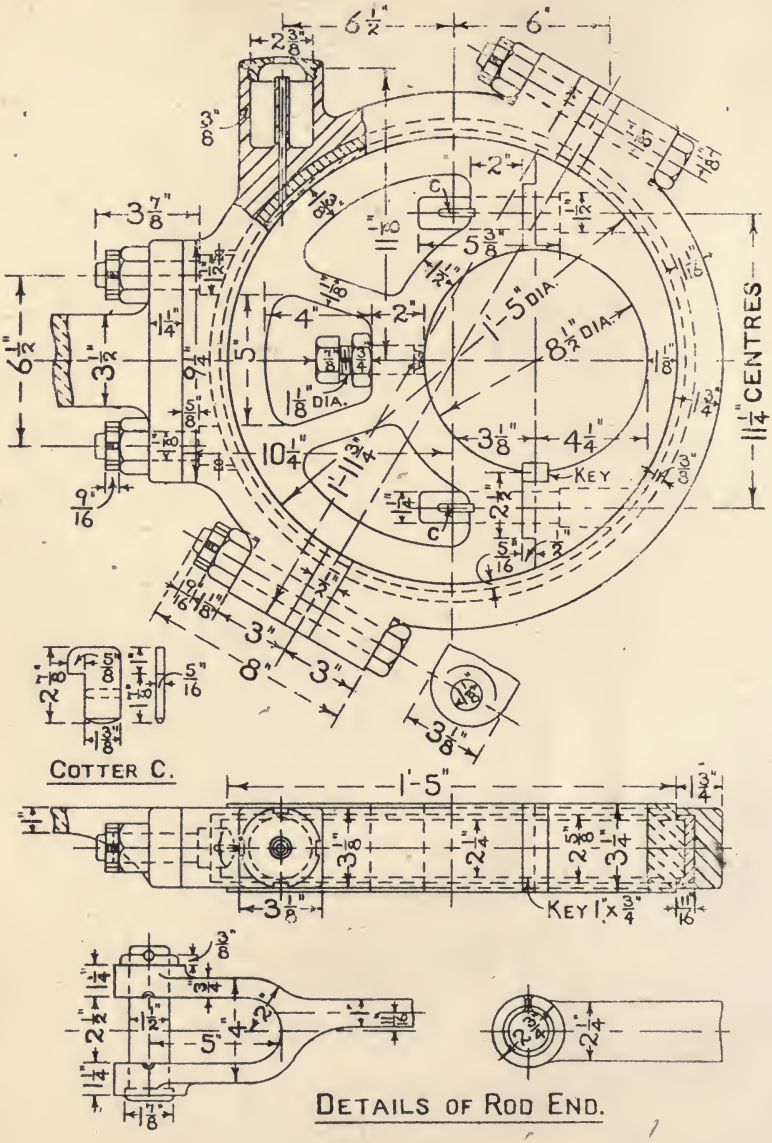
Supplied by the late

MR. F. W. WEBB, M.INST.C.E.,

Formerly Chief Engineer, CREWE.

DETAILS OF ECCENTRIC.

GREAT WESTERN RAILWAY.



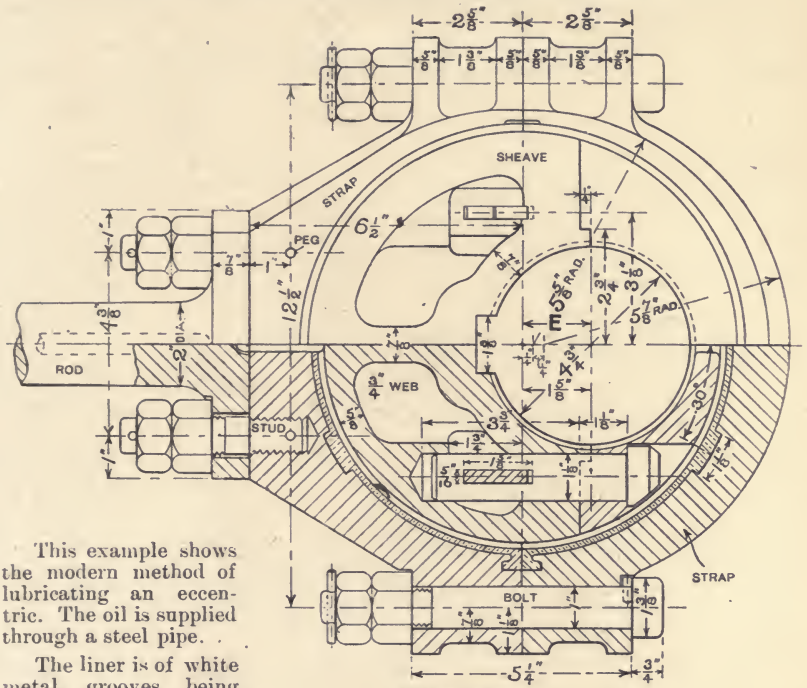
Supplied by

Mr. G. J. CHURCHWARD, M.Inst.C.E., M.I.M.E.,

Chief Mechanical Engineer, SWINDON.

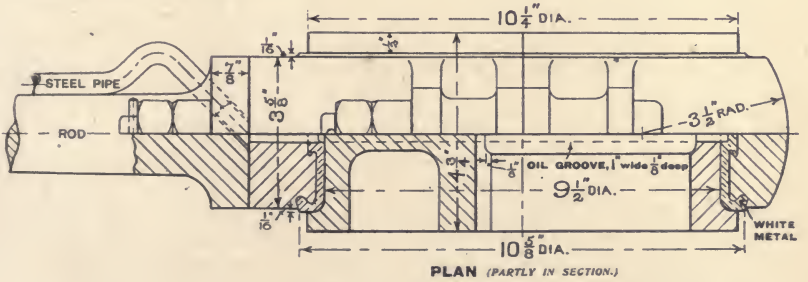
DETAILS OF ECCENTRIC.

FOR BELLISS' STANDARD ENGINE.



This example shows the modern method of lubricating an eccentric. The oil is supplied through a steel pipe.

The liner is of white metal, grooves being cast in the strap, into which the metal is run.



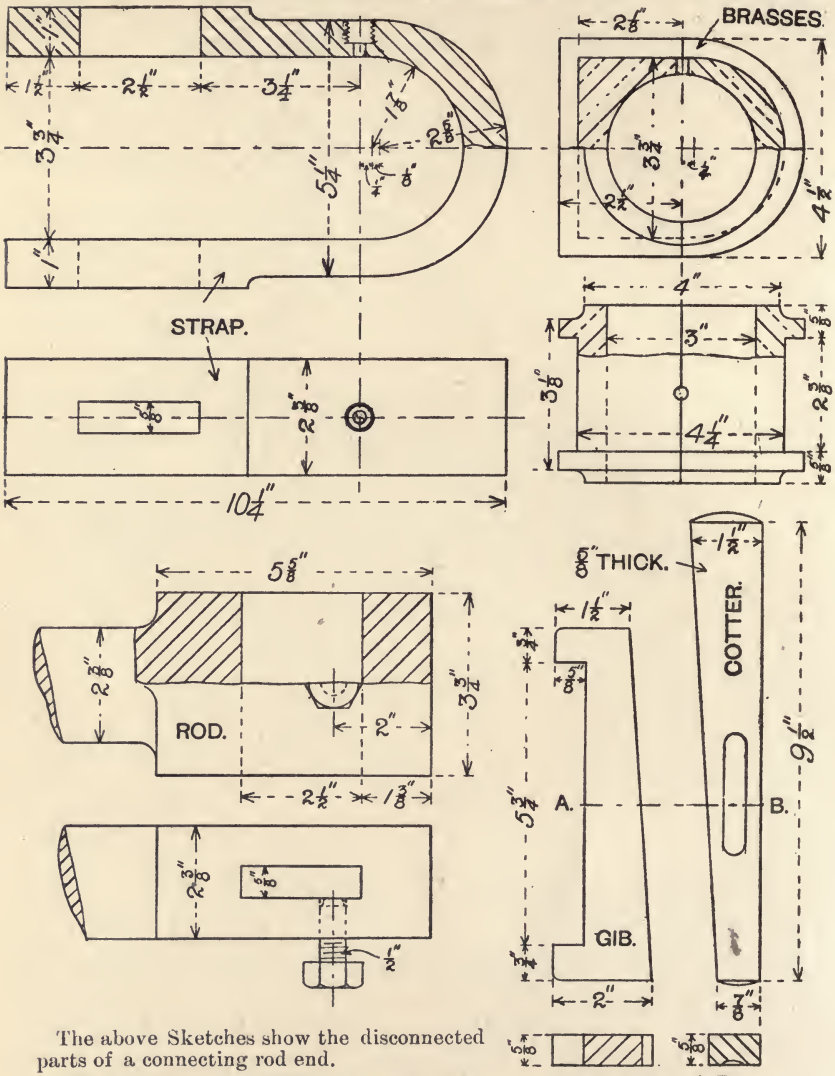
An Eccentric is used for working the valve gear in steam engines, &c.

It converts circular into reciprocating rectilinear motion.

The distance marked **E** on sketch is termed "eccentric radius," and the "throw" equals twice the radius, which is the travel of the valve.

Supplied by
Messrs. BELLISS & MORCOM, Limited,
Engineers. BIRMINGHAM.

— DETAILS OF CONNECTING ROD END. —



The above Sketches show the disconnected parts of a connecting rod end.

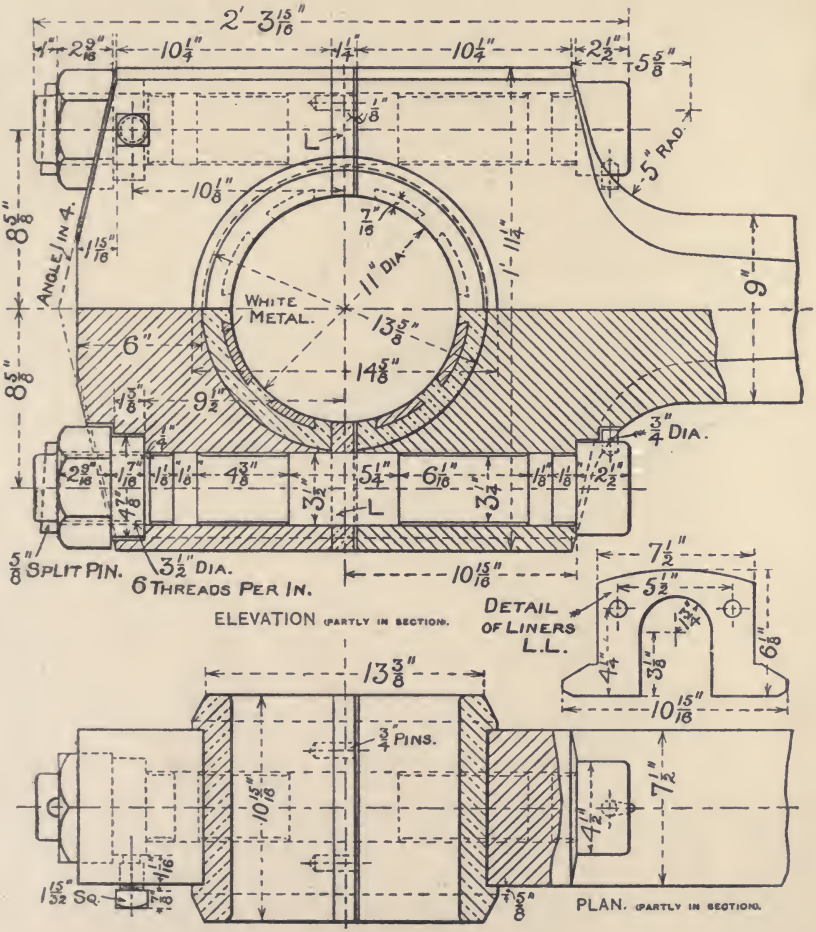
The strap passes round the brasses, and fits upon the flat end of the rod, which is slotted; corresponding slots are cut through the two sides of the strap. The gib and cotter pass through these slots, and draw the brasses tightly together, clearance being left in the slots to admit of the *draw* of the cotter.

The heads of the gib fit exactly on the outside of the strap, and keep it in contact with the flat end of the rod. The set screw prevents the cotter from "*slacking back.*"

Draw the connecting rod end in its proper working position. Show five views, viz., elevation (with top half in section), two end elevations, horizontal section, and plan. SCALE: FULL SIZE.

— DETAILS OF CONNECTING ROD END. —

FOR TANDEM CORLISS ENGINE.



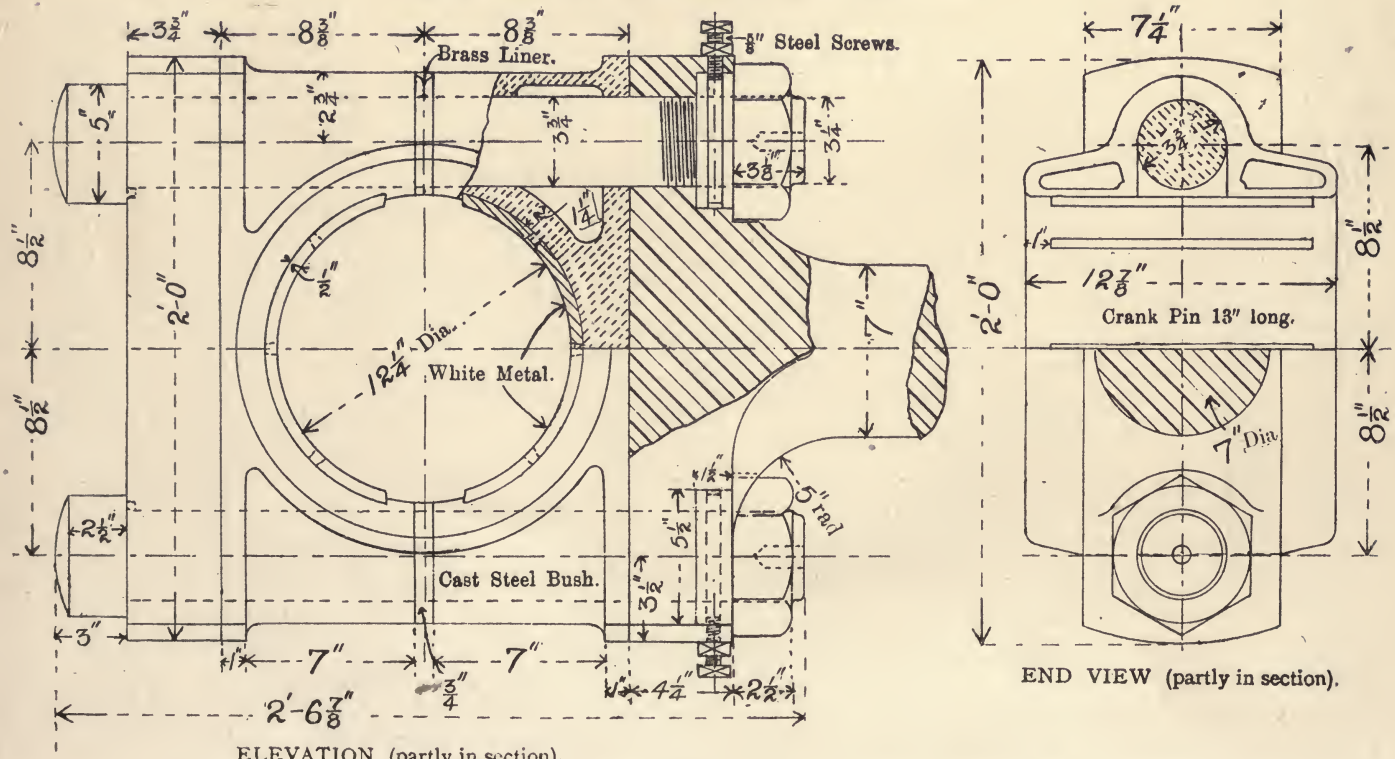
Supplied by

Messrs. GALLOWAYS' LIMITED

Knott Mill Iron Works, MANCHESTER.

CONNECTING ROD END.

FOR MARINE ENGINES OF 1,500 I.H.P.



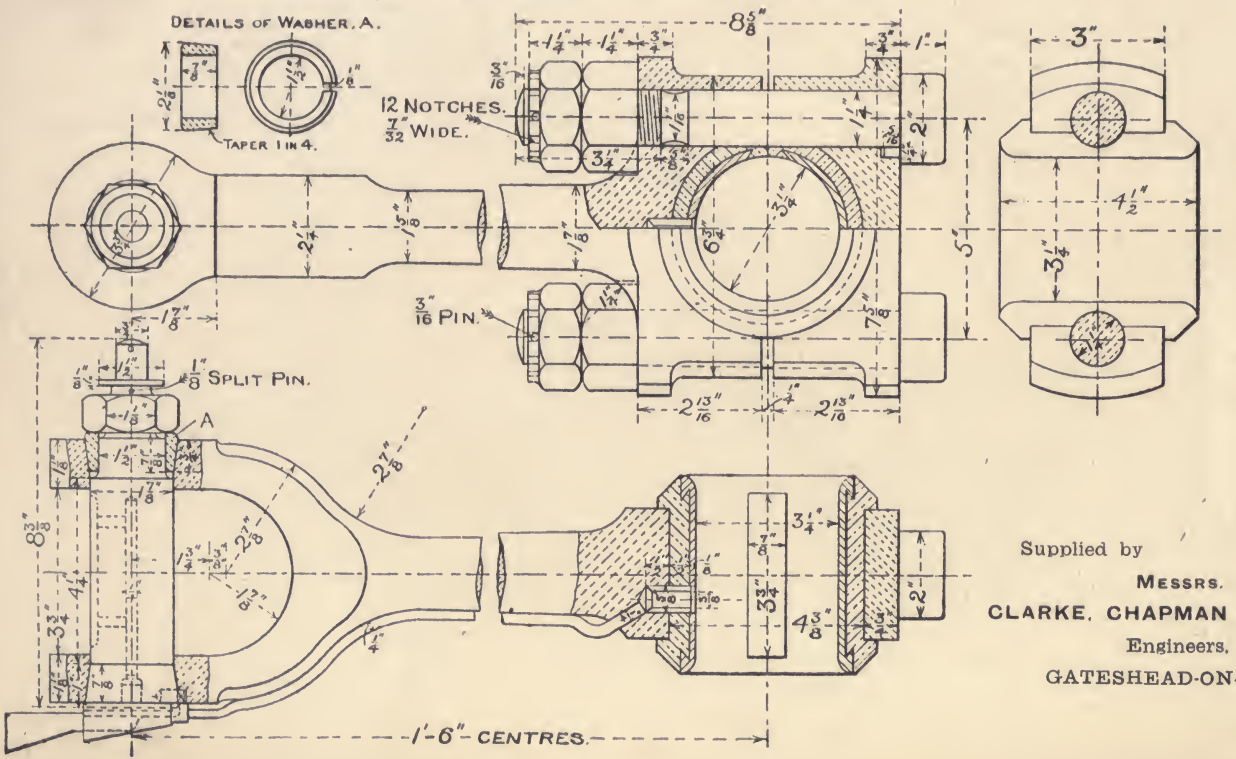
ELEVATION (partly in section).

END VIEW (partly in section).

Supplied by Messrs. RICHARDSONS, WESTGARTH & CO., Limited, Engineers, MIDDLESBROUGH.

DETAILS OF CONNECTING ROD.

8" STROKE SINGLE ENGINE.



Supplied by

MESSRS.

CLARKE, CHAPMAN & Co. LTD.,

Engineers,

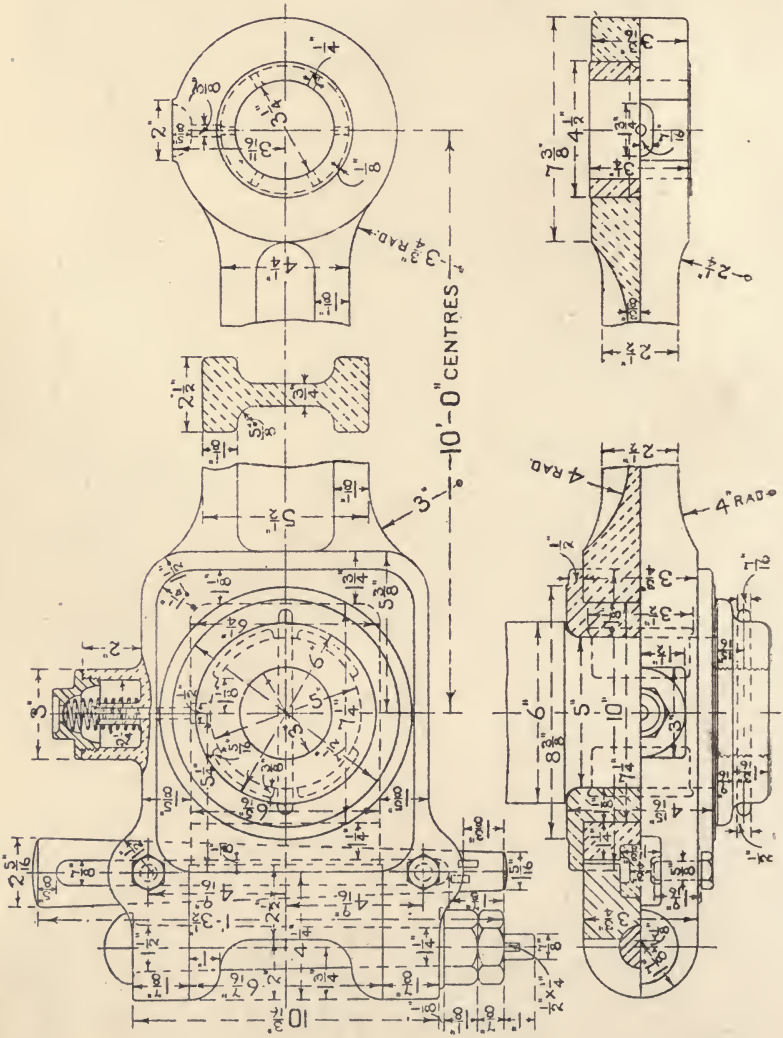
GATESHEAD-ON-TYNE.

— DETAILS OF CONNECTING ROD. —

GREAT NORTHERN RAILWAY.

AS USED ON THE 6′ 6″ FOUR WHEELS COUPLED PASSENGER ENGINES.

Finished Weight, 4 cwts. 15 lbs.



Supplied by

Mr. H. N. GRESLEY, M.I.M.E.,

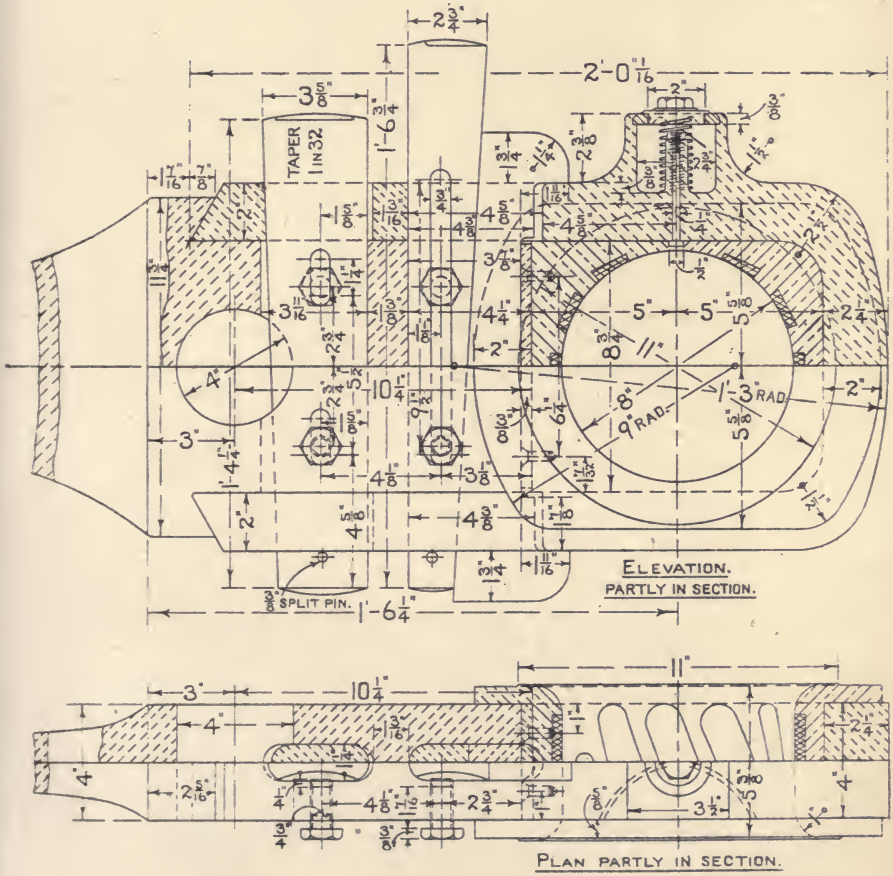
Locomotive Engineer, DONCASTER.

— DETAILS OF CONNECTING ROD END. —

LONDON AND NORTH WESTERN RAILWAY.

As used on the

"GEORGE THE FIFTH" Class of Express Passenger Engines.



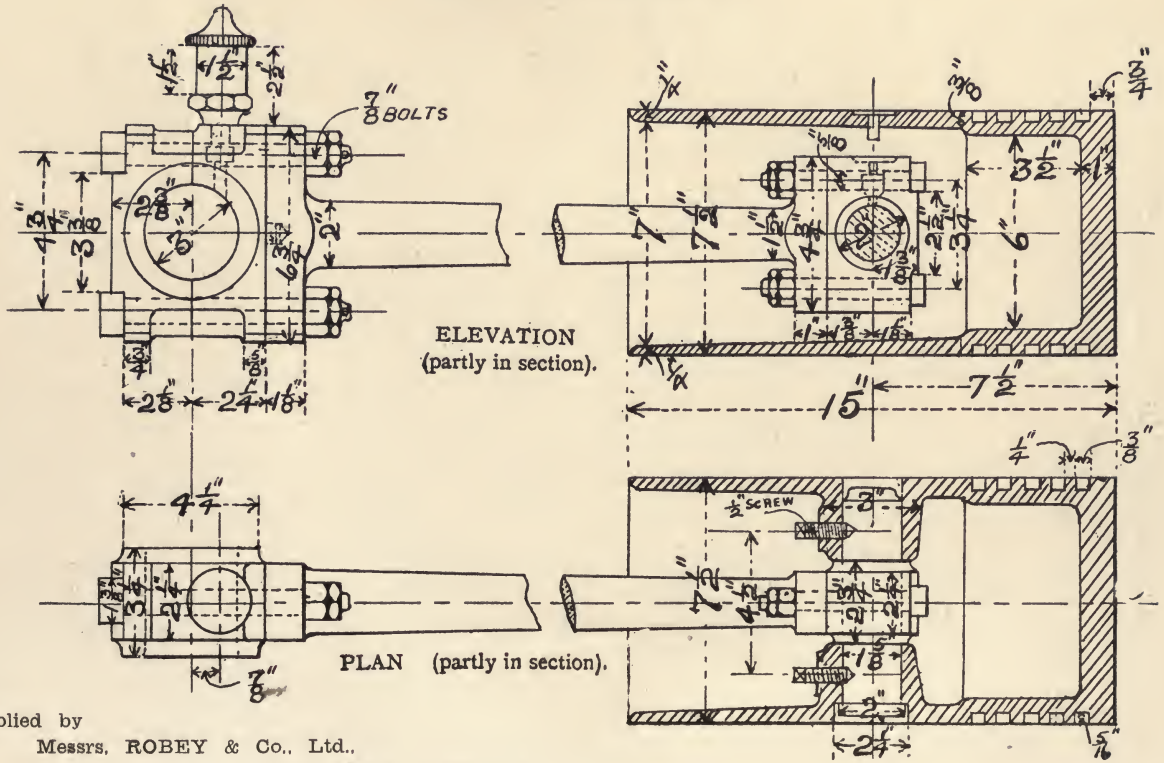
Supplied by

Mr. C. J. B. COOKE, M.Inst.C.E.,

Chief Mechanical Engineer, CREWE.

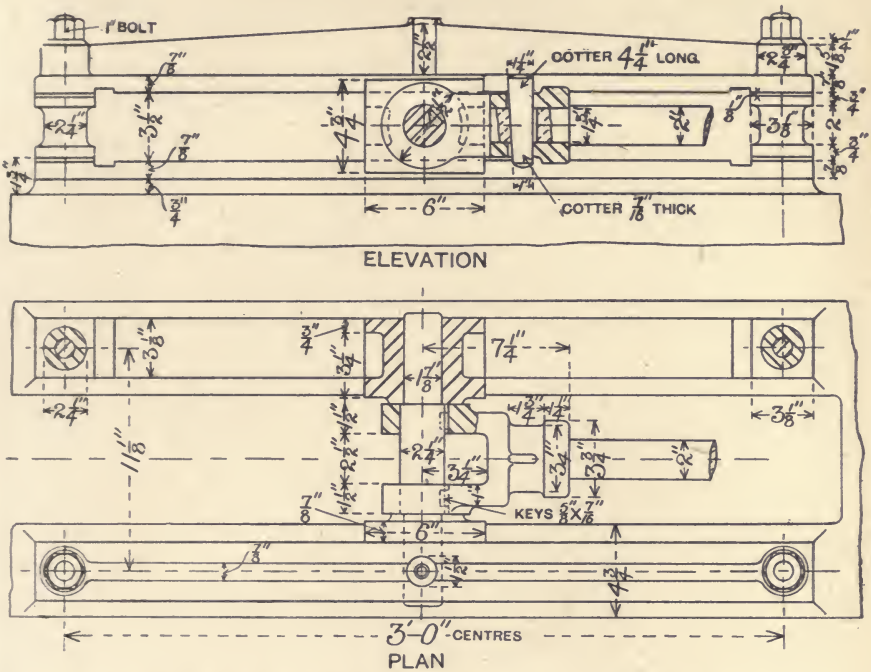
PISTON AND CONNECTING ROD.

ROBEY GAS ENGINE.



Supplied by
Messrs. ROBEY & Co., Ltd.,
Globe Works, LINCOLN.

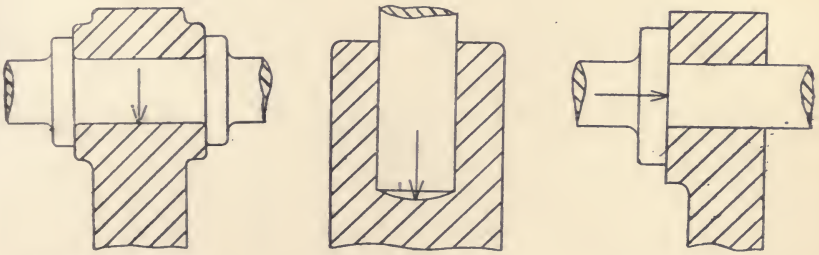
— SLIDE BARS, SLIDE BLOCKS AND CROSSHEAD —



The above sketch shows the general arrangement of the slide bars, slide blocks and crosshead for a horizontal engine.

The bed, bars, blocks and distance pieces are of cast iron. The bars are secured to the engine bed by means of four bolts.

Show by means of sketches (1) a journal bearing, (2) a pivot bearing, and (3) a collar bearing, as used for supporting shafting, and indicate by arrows the direction of the pressure on the bearing in each case.



JOURNAL BEARING. PIVOT BEARING. COLLAR BEARING.

(See page 34 for Vertical Thrust Bearing.)

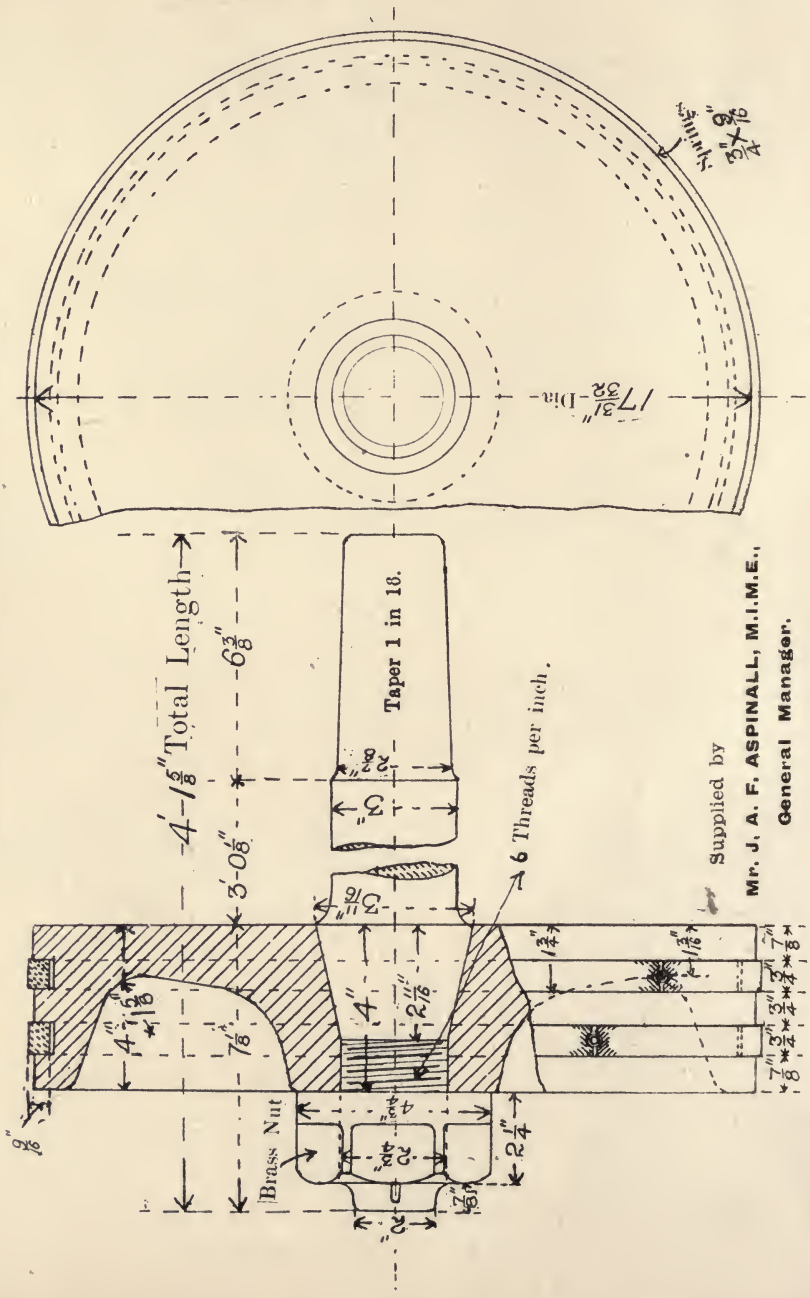
— PISTONS. —

Give sketches showing the construction of one form of Piston suitable for a Locomotive Engine.

(100)

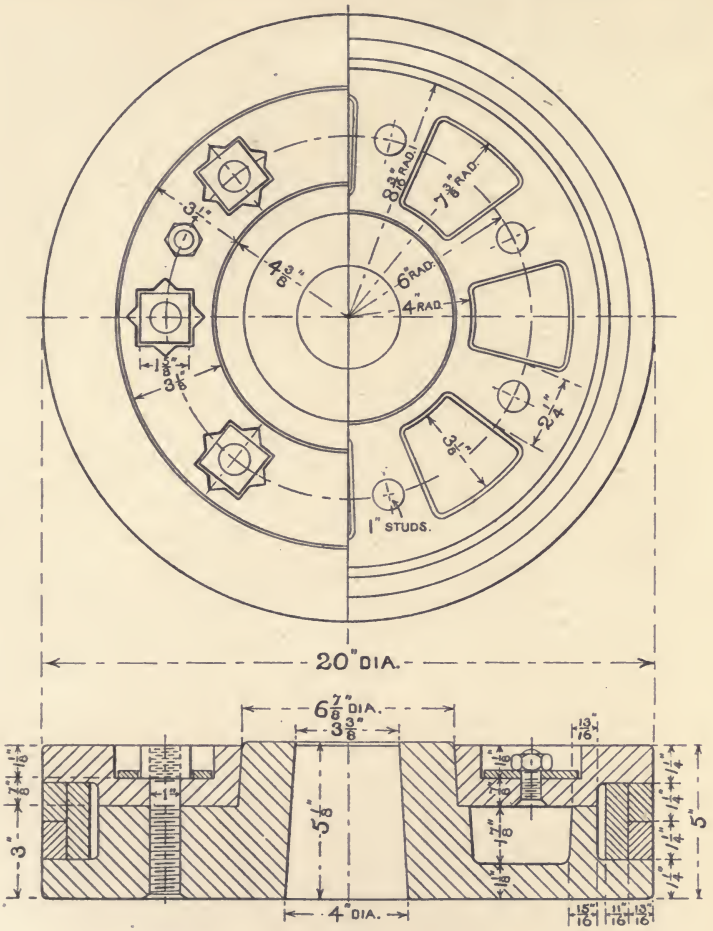
— DETAILS OF PISTON AND ROD. —

LANCASHIRE AND YORKSHIRE RAILWAY.



DETAILS OF PISTON.

FOR LONG-STROKE FIXED STEAM ENGINE.



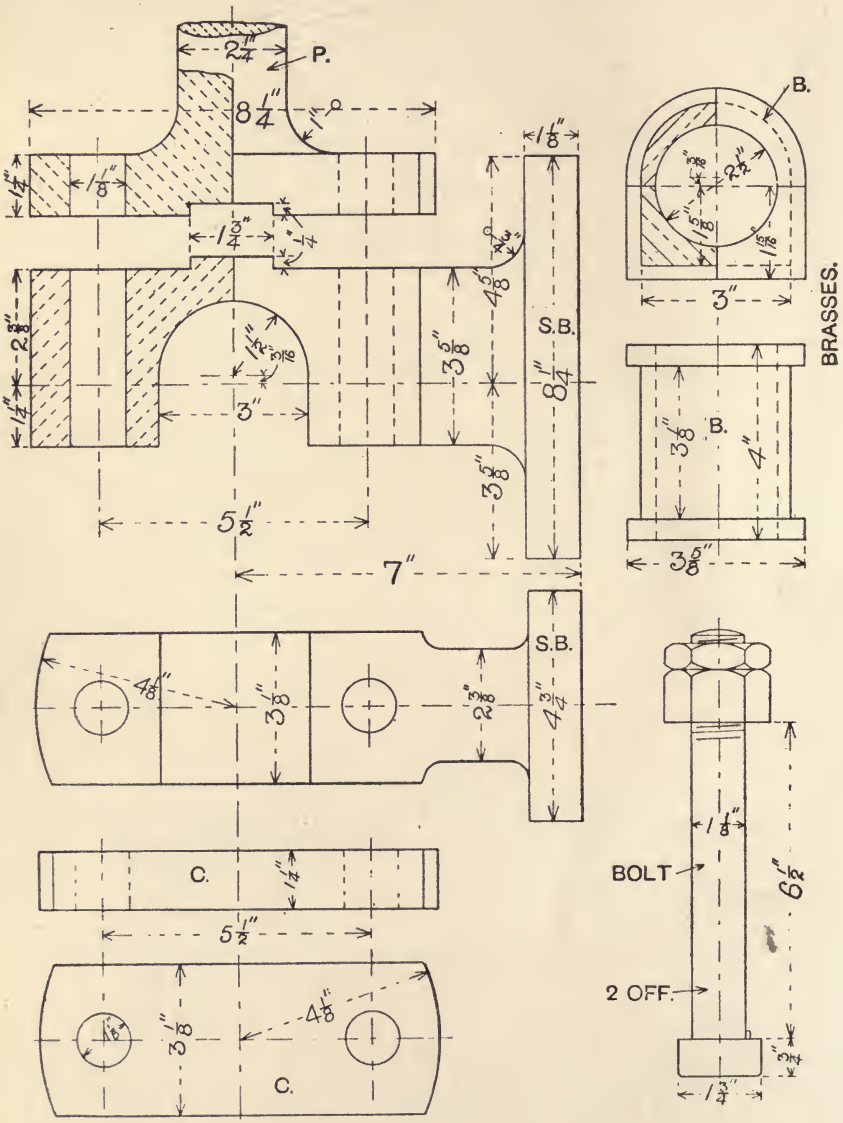
The body of the piston shown above is of cast iron. Two cast iron rings are used to make the piston steam tight, an inner ring of cast iron pressing these outwards against the walls of the cylinder. The junk ring or cover holds the spring rings in position. The cover is secured to the body of the piston by means of seven 1" dia. studs provided with square nuts. A locking plate or ring is dropped into position to prevent the nuts from working loose, the plate being secured to the body of the cover by three $\frac{5}{8}$" dia. screws.

Supplied by

Messrs. **RUSTON, PROCTOR & CO., Limited.**

Sheaf Iron Works, LINCOLN.

CROSSHEAD FOR VERTICAL STEAM ENGINE.

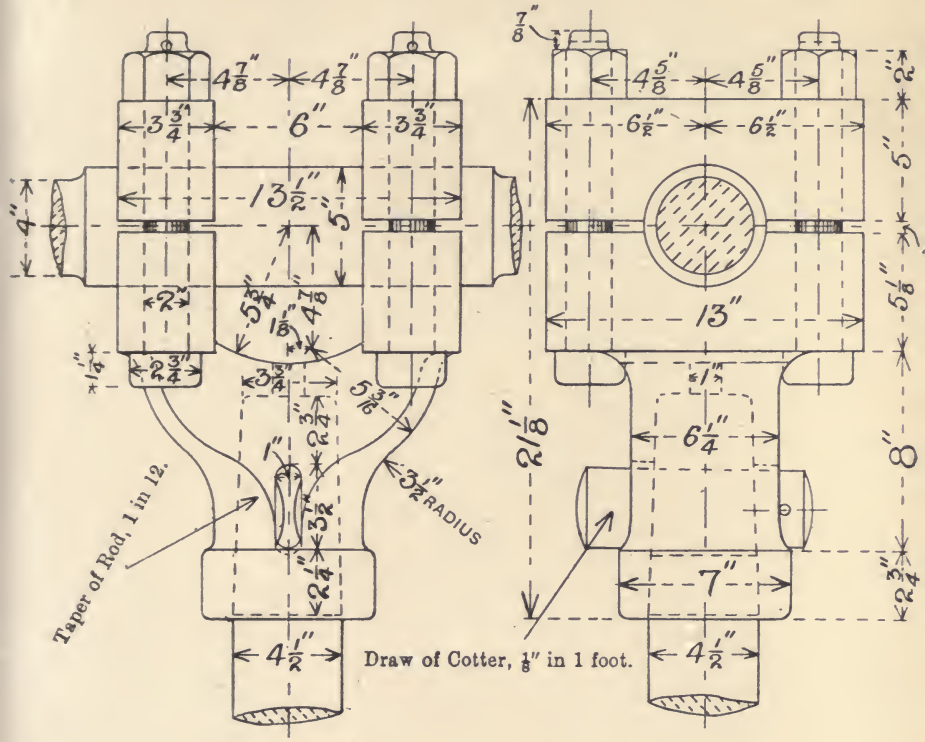


The above sketches show the disconnected details of a steel crosshead, suitable for a vertical engine. The piston rod P. has an end forged to it, which carries the slide block S.B. and the brasses B. The parts are held together by means of the cap C. and the two bolts.

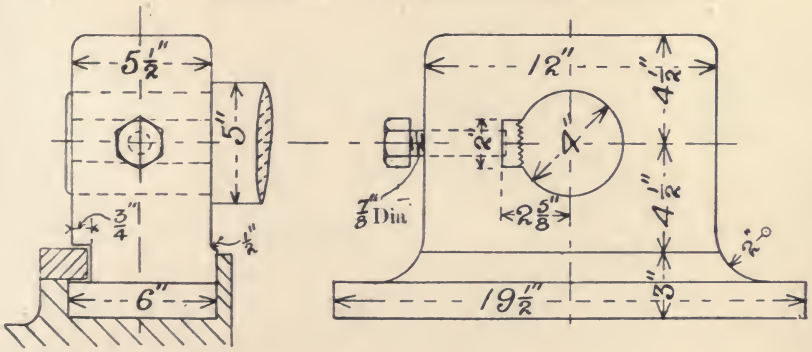
You are required to draw the parts fitted together in their working position. Show two elevations partly in section, and a plan. SCALE: FULL SIZE.

DETAILS OF CROSSHEAD.

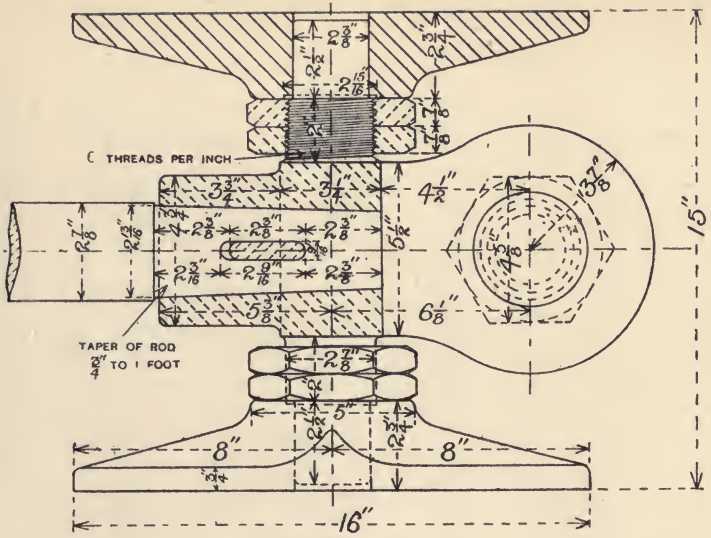
FOR HORIZONTAL ENGINE.



DETAILS OF SLIDE BLOCKS.

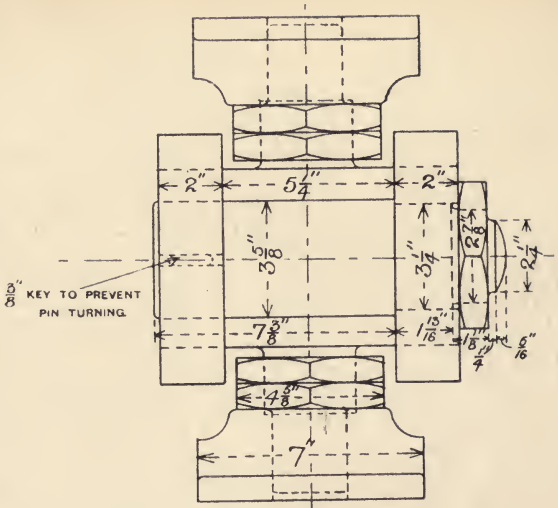


Supplied by
Messrs. POLLIT & WIGZELL, Limited,
Engineers, SOWERBY BRIDGE.

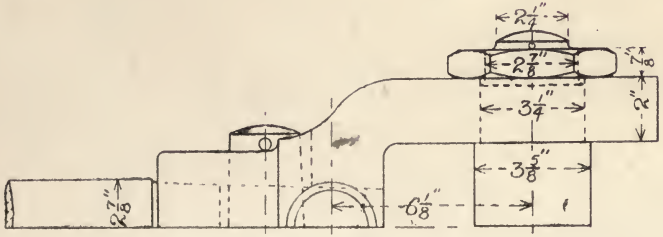


ELEVATION

(PARTLY IN SECTION)



END ELEVATION



HALF PLAN

— DETAILS OF CROSSHEAD. —

AS USED FOR

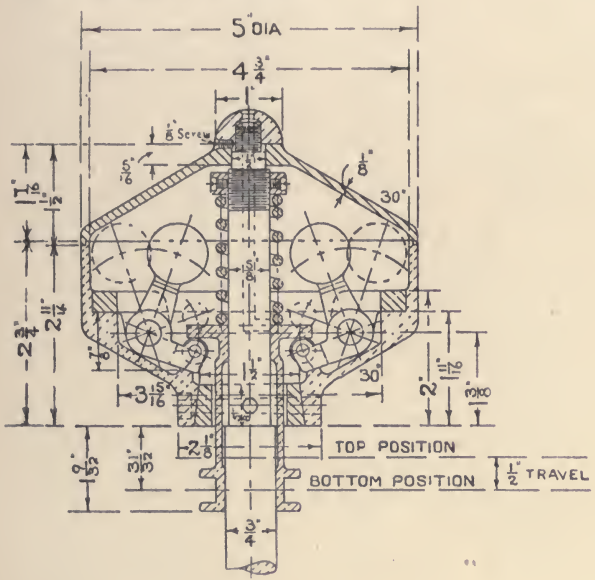
14" × 36" CORLISS ENGINE.

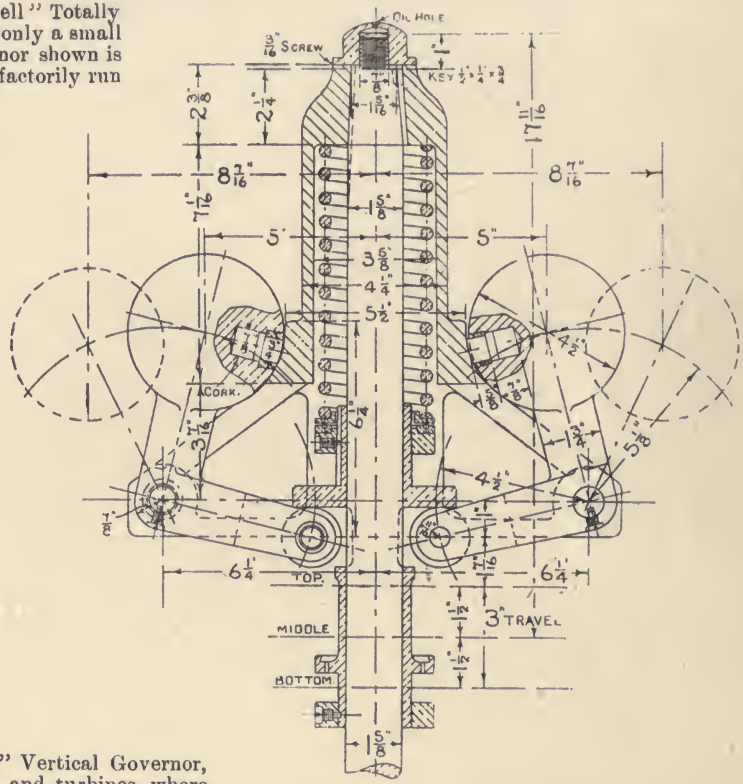
Supplied by

Messrs. E. R. & F. TURNER, Limited,

Engineers, IPSWICH.

The smaller drawing is a sectional elevation of the "Hartnell" Totally Enclosed Spring Governor, as used on gas and oil engines where only a small sleeve travel is required. The usual mean speed of the Governor shown is 500 to 1000 revs. per minute, though the Governor may be satisfactorily run up to 2000 revs. per minute.



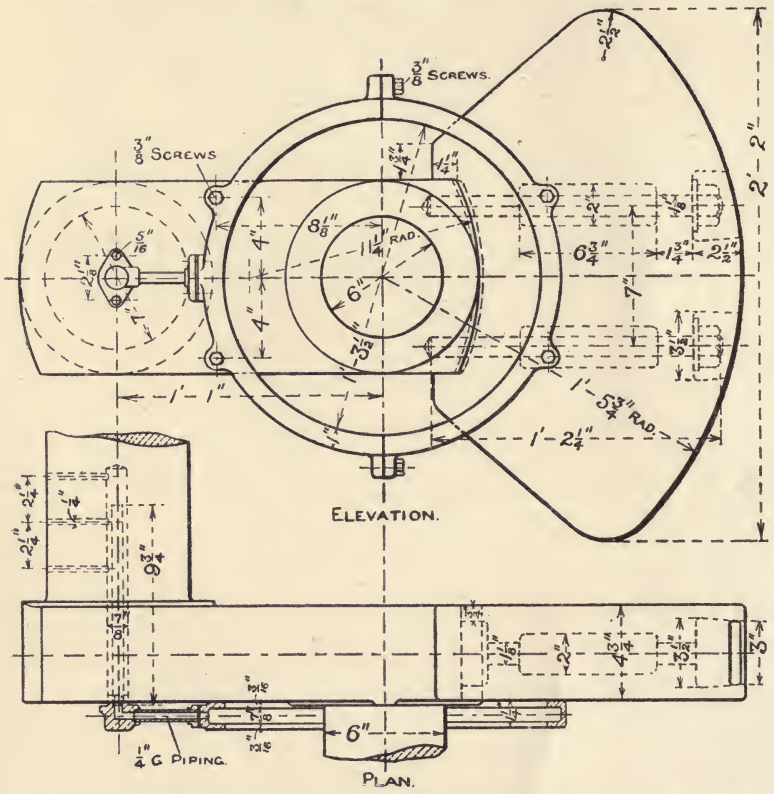


The larger drawing shows the standard type of "Hartnell" Vertical Governor, which is used for governing mill engines, electric light engines, and turbines, where the steam is controlled by automatic expansion gear or equilibrium throttle valves. The usual mean speeds for this size of Governor are 240 and 280 revs. per minute.

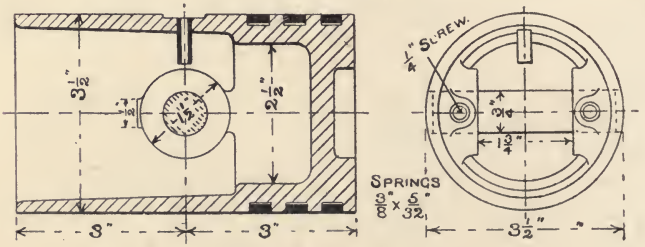
Supplied by Messrs. **WILSON HARTNELL & CO.** Limited, Volt Works, **LEEDS.**

DETAILS OF BALANCE WEIGHTS AND OILING ARRANGEMENT.

FOR 50 B.H.P. OIL ENGINE.



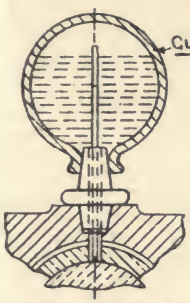
PISTON FOR AIR COMPRESSOR.



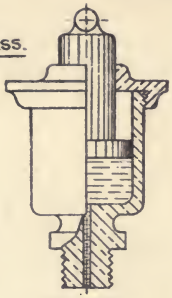
(See page 112.)

Supplied by
Messrs. THE CAMPBELL GAS ENGINE CO., Limited.
HALIFAX.

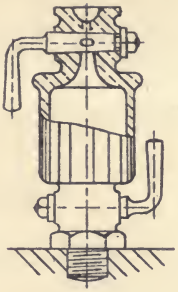
LUBRICATORS.



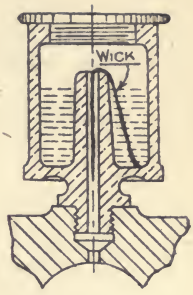
NEEDLE LUBRICATOR.



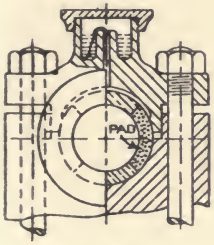
WEIGHTED LUBRICATOR.



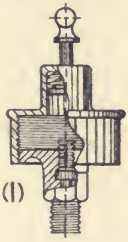
OIL CUP.

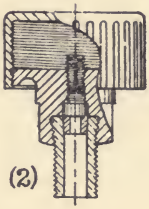


SYPHON LUBRICATOR

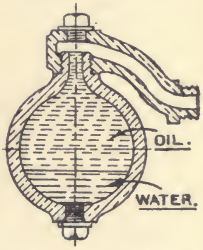


PAD LUBRICATION.

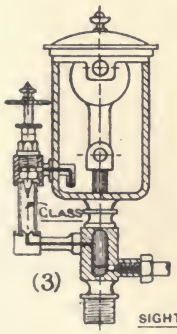


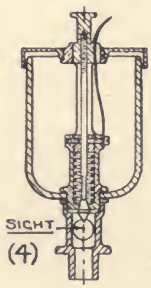


STAUFFER'S LUBRICATORS.



DISPLACEMENT LUBRICATOR.





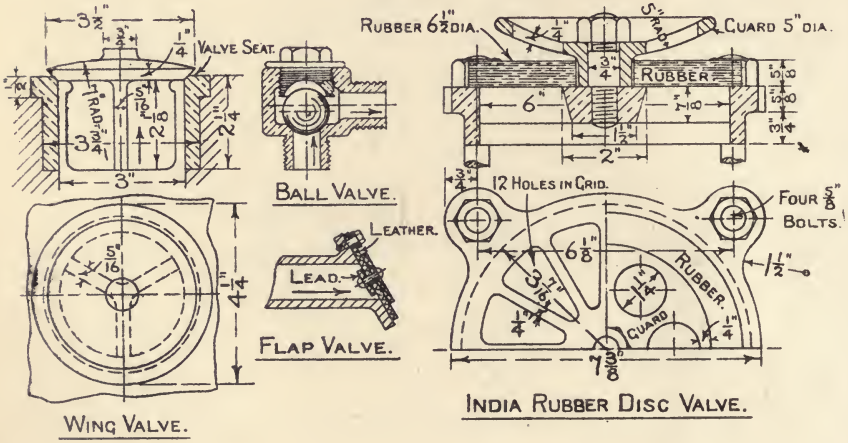
SIGHT FEED LUBRICATORS.

STAUFFER'S LUBRICATORS.— Example 1 shows the "Tell-Tale" Lubricator, which combines screw pressure action for forcing the lubricant into the bearing with delicate spring pressure action for automatically continuing the feed after the screw pressure ceases. The feed of the Lubricant can be regulated by means of a slotted screw in the shank. Example 2 shows a lubricator with screw pressure action only. Messrs Trier Bros., London, S.W., are the makers.

SIGHT FEED LUBRICATORS.— (3) shows an example where the lubricant is forced to the bearing by an eccentric and ram. The eccentric shaft being connected to some suitable part of the engine. The path of the lubricant is shown by the thick black line. This patent vacuum sight feed lubricator is made by Messrs. W. Lees & Co., Ltd., Halifax. (4) "Hartnell" Sight Feed Lubricator. The flow of the lubricant is started by pressing the spindle, regulated by twisting the milled head and stopped by touching the trigger. It can be readily adjusted to give from one to several drops per minute. Messrs. Wilson Hartnell & Co., Ltd., Volt Works, Leeds, are the makers.

VALVES.

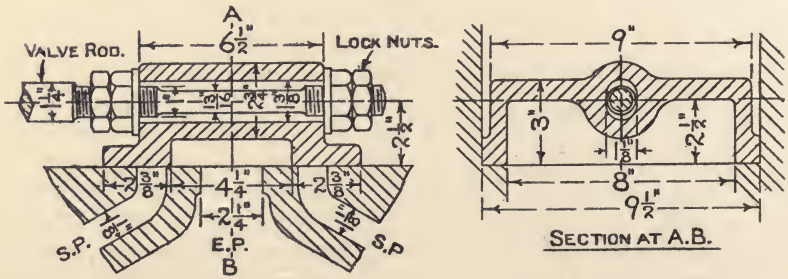
Give sketches showing (1) the construction of an ordinary Wing Valve and Seat. (2) Ball Valve. (3) Leather Flap or Check Valve. Also show the construction of an India Rubber Disc Valve as used on pumps.



DOUBLE BEAT VALVES.—For an example of this type of Valve see the Regulator Valve, pages 80 and 81.

SIMPLE "D" SLIDE VALVE.

Give sketches showing the construction of the ordinary **D** Slide Valve employed on Steam Engines. Show the Valve in its central position over the Steam Ports and indicate clearly the Steam and Exhaust Laps.

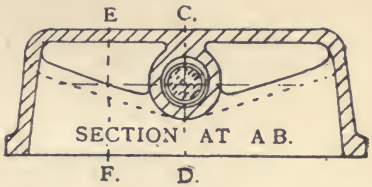


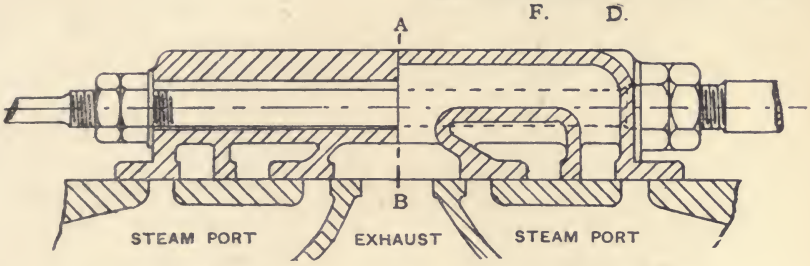
S. P.—STEAM PORTS. E. P.—EXHAUST PORT.

— DOUBLE-PORTED SLIDE VALVE. —

— FOR —

MARINE ENGINES.

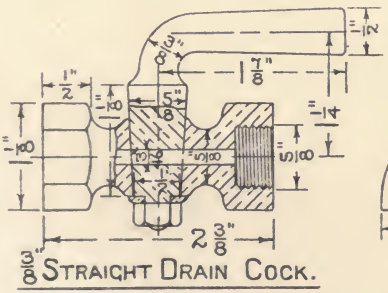




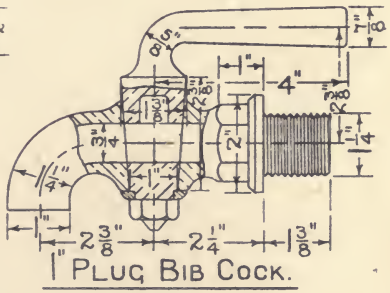
SECTION AT C.D. SECTION AT E.F.

The object of using a Double-ported Slide Valve in large Marine Engines, is to lessen the power required to drive the valve, by reducing the travel. This is effected by making the Slide Valve and steam passages double-ported. The same amount of opening is obtained with half the travel which an ordinary D Slide Valve would require, and consequently much less power is required to drive it.

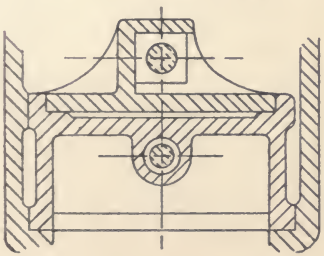
Give sketches showing (1) a $\frac{3}{8}$" Straight Drain Cock, (2) a 1" Plug Bib Cock, (3) Meyers Expansion Valve.



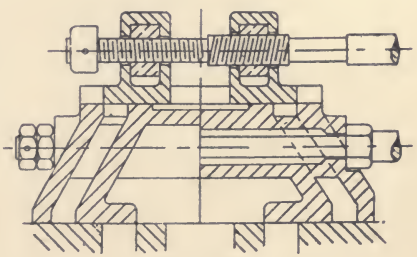
3/8" STRAIGHT DRAIN COCK.



1" PLUG BIB COCK.

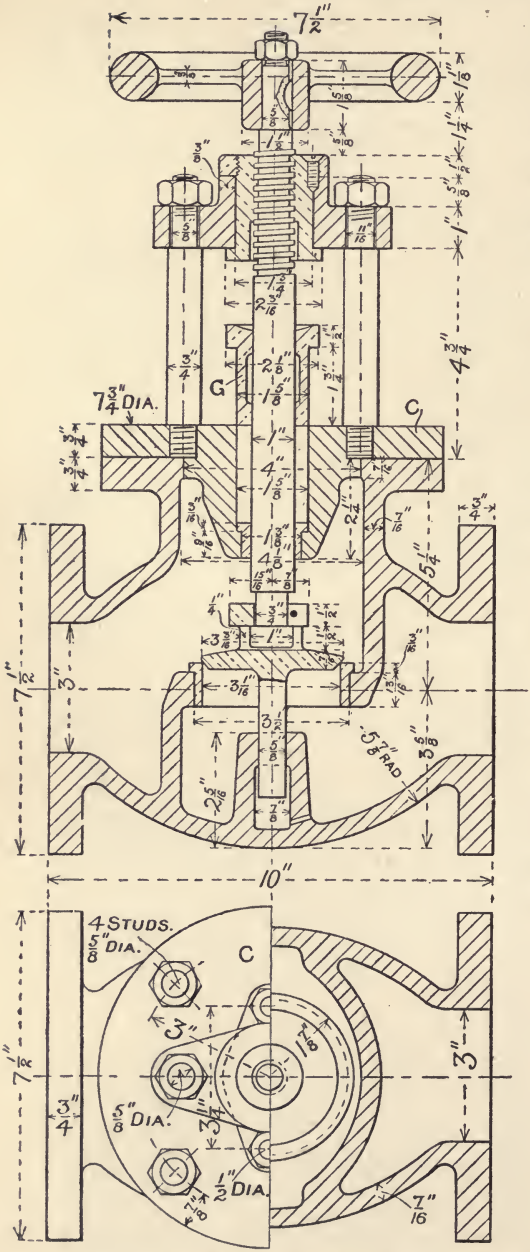


SECTION THROUGH CENTRE.



SECTIONAL PLAN.

3″ STOP VALVE.



This drawing shows the construction of an improved stop valve suitable for 3″ pipes. It is used for regulating the supply of steam from a boiler to the cylinder of a steam engine, and for other purposes where steam is employed.

The cover C, is fastened to the body of the valve by means of four ⅝″ dia. studs, the diameter of the circle for the studs is 6 inches.

The gland G, is secured to the cover by two studs ½″ dia., which provides for adjustment of packing.

The spindle is made of manganese bronze, and the screwed part has 4 threads per inch.

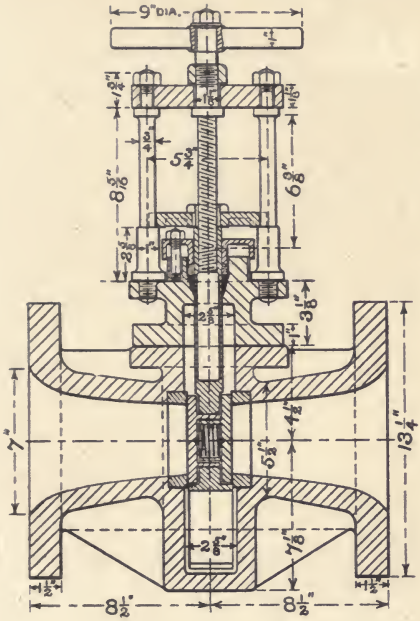
DRAW THIS EXAMPLE.

SCALE = Half size. Add two elevations, and also a complete plan with the handwheel removed.

Supplied by Messrs. ISAAC STOREY & SONS, Engineers, MANCHESTER.

STOP VALVE.

HOPKINSON–FERRANTI PATENT.



This valve has been invented and designed to enable a valve having operative parts of half the ordinary diameter to pass a large amount of steam through a small working part.

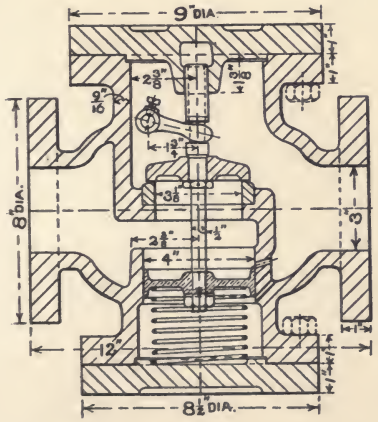
The principle of working is to convert the pressure of the fluid into velocity and re-convert the velocity into pressure, thereby passing an amount of steam equal to the full carrying capacity of the pipe.

The discs slide with a flexible pressure upon the seats, thereby preventing cutting and scoring.

Both the discs and seats are made of Hopkinson's "Platnam" metal which is specially suited for superheated steam.

HOPKINSON'S PATENT.

AUTOMATIC "EXPLOSION" VALVE.



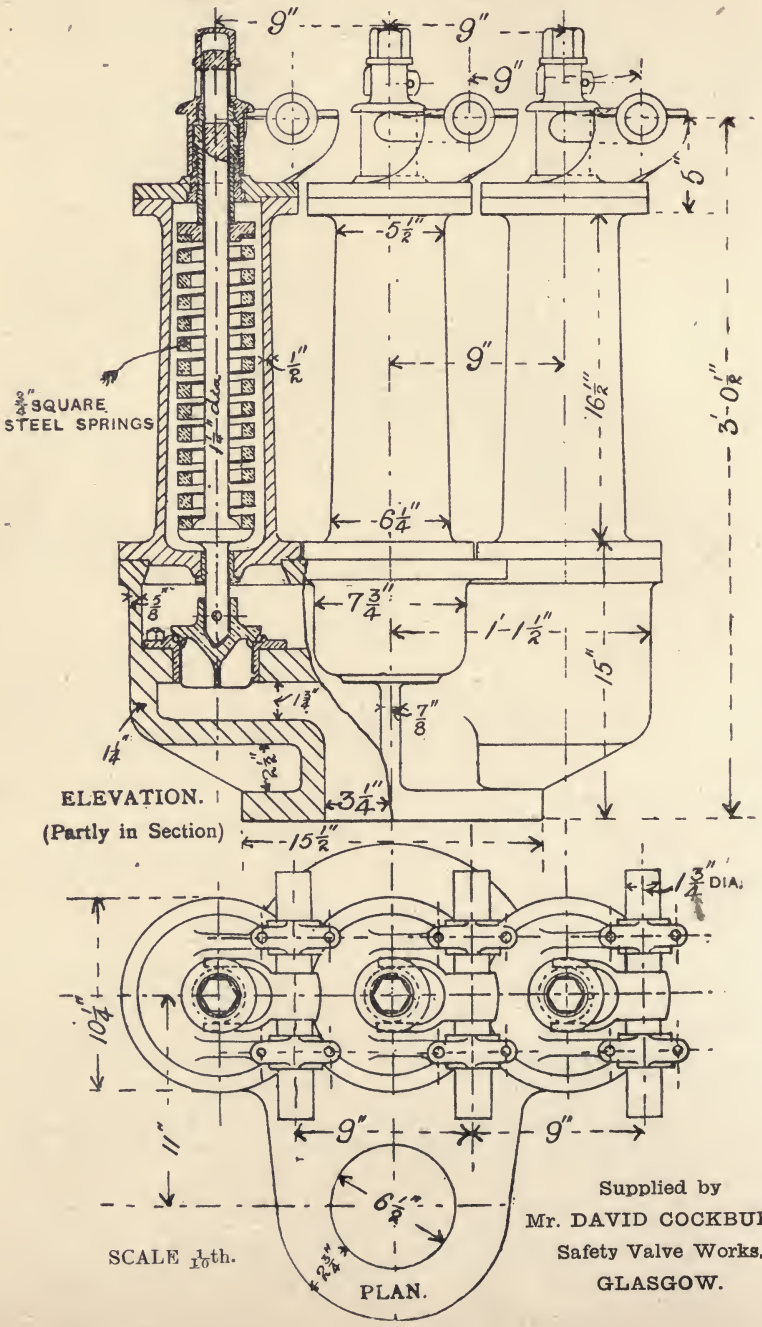
The body and covers of this valve are of mild Siemens-Martin steel, and the seat is of "Platnam" metal.

This valve adjusts itself automatically for the varying demands of steam, and in the case of a pipe bursting, it closes quickly but gently. The flow of steam from the boiler tends to open the valve, therefore it cannot be closed by excessive flow of steam. This is an important feature as it prevents the valve closing when not required.

Supplied by
Messrs. J. HOPKINSON & CO., Limited,
Britannia Works, HUDDERSFIELD.

CUNARD S.S. "CAMPANIA" AND "LUCANIA."

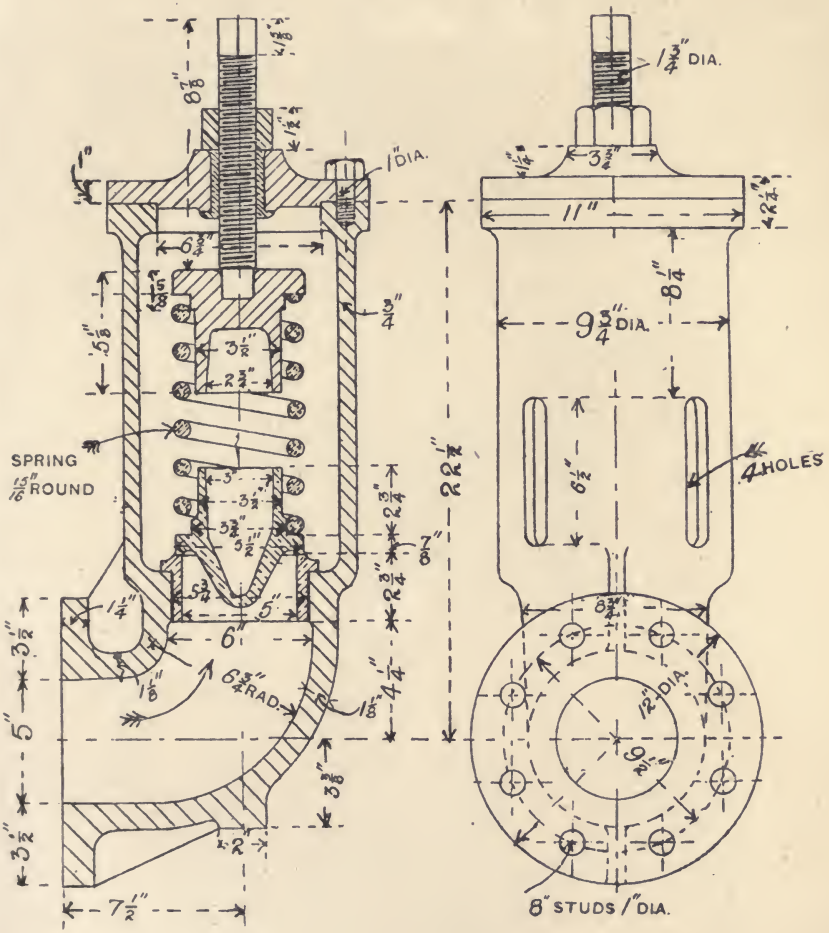
— TRIPLE SAFETY VALVES. —



Supplied by
Mr. DAVID COCKBURN.
Safety Valve Works.
GLASGOW.

CUNARD S.S. "CAMPANIA" AND "LUCANIA."

— CYLINDER ESCAPE VALVE. —



SECTIONAL ELEVATION. ELEVATION.

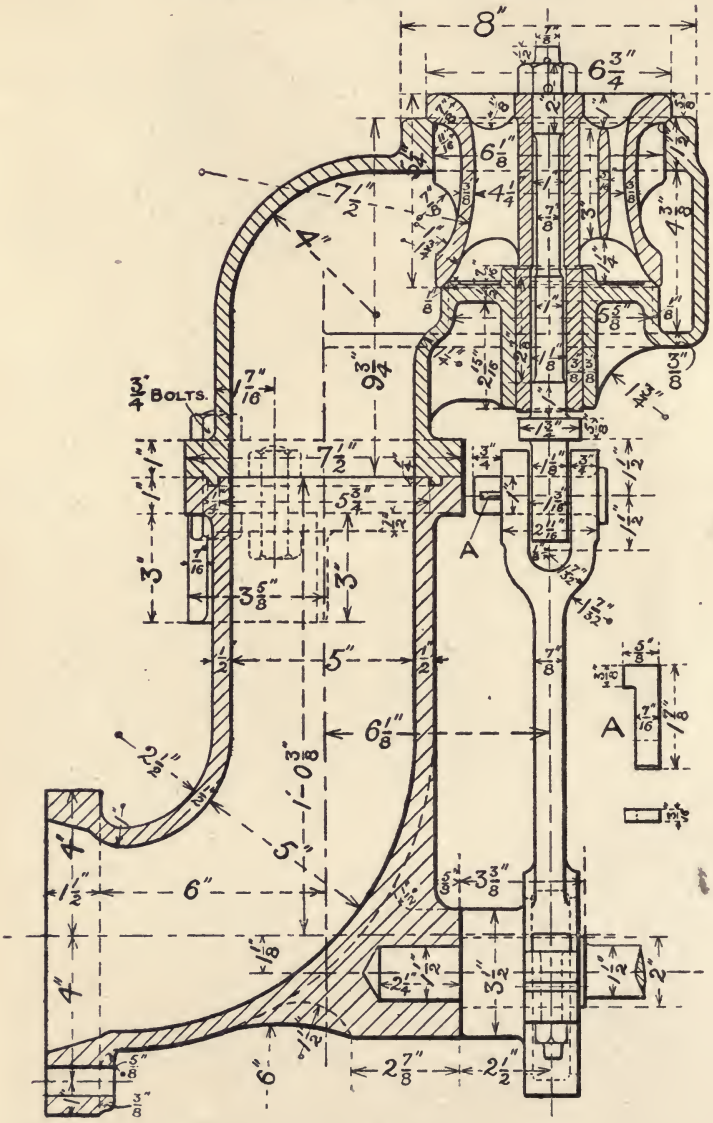
PARTICULARS OF ENGINES.

Each of the Twin Engines has TWO H.P. CYLINDERS, 37″ diameter, ONE M.P. 79″ diameter, and TWO L.P. 98″ diameter, by 5′ 9″ STROKE. The Collective I.H.P. of the Two Sets is about 28,500.

Supplied by
Messrs. THE CUNARD S.S. Co., Ltd., LIVERPOOL.

DOUBLE-BEAT REGULATOR VALVE.

NORTH EASTERN RAILWAY.



SECTIONAL ELEVATION.

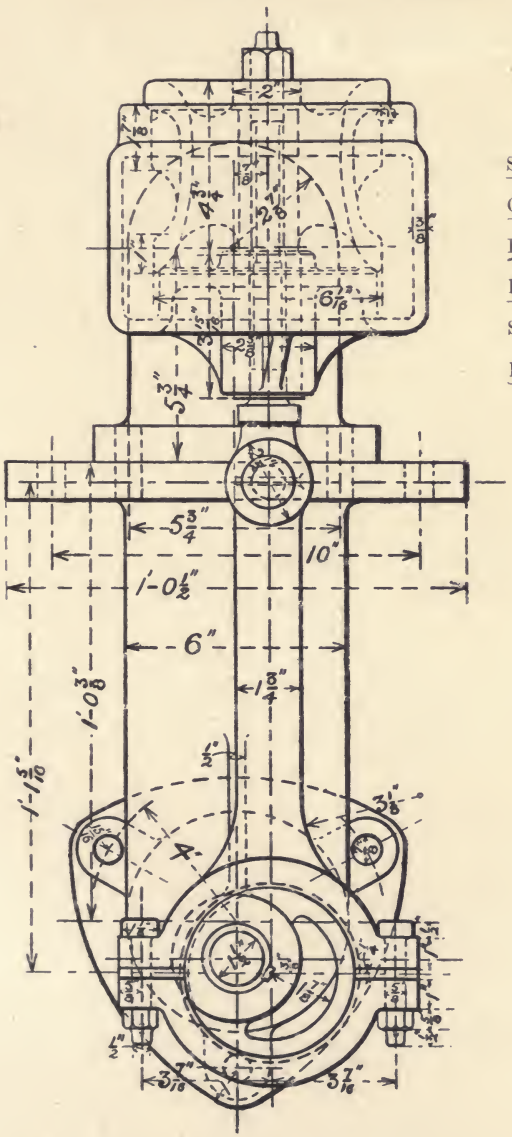
Supplied by

MR. WILSON WORSDELL, M.INST.C.E., M.I.M.E.,

Late Chief Engineer, N.E.Ry., GATESHEAD.

— DOUBLE-BEAT REGULATOR VALVE. —

NORTH EASTERN RAILWAY.



See Opposite Page For Sectional Elevation.

— END ELEVATION. —

Supplied by
Mr. WILSON WORSDELL, M.Inst.C.E., M.I.M.E.,
Late Chief Engineer, N.E.Ry., GATESHEAD.

DETAILS OF SAFETY VALVES.

MIDLAND RAILWAY.

FOR EXPRESS PASSENGER ENGINE.

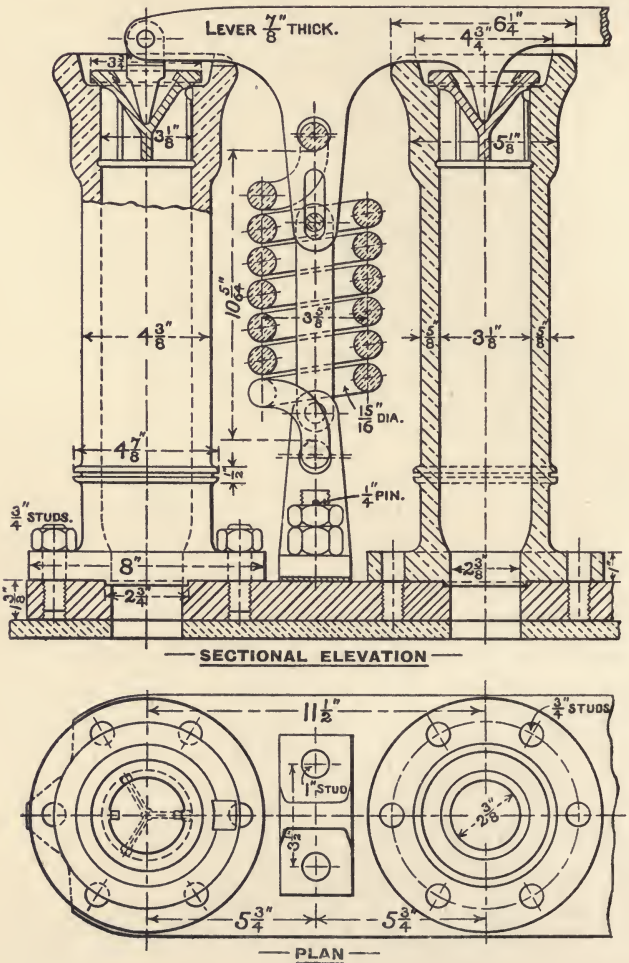


FIG. 1.

(See Opposite Page.)

Supplied by

Mr. R. M. DEELEY, M.I.M.E.,

Late Chief Engineer, DERBY

— DETAILS OF SAFETY VALVES. —

MIDLAND RAILWAY.

— FOR EXPRESS PASSENGER ENGINE. —

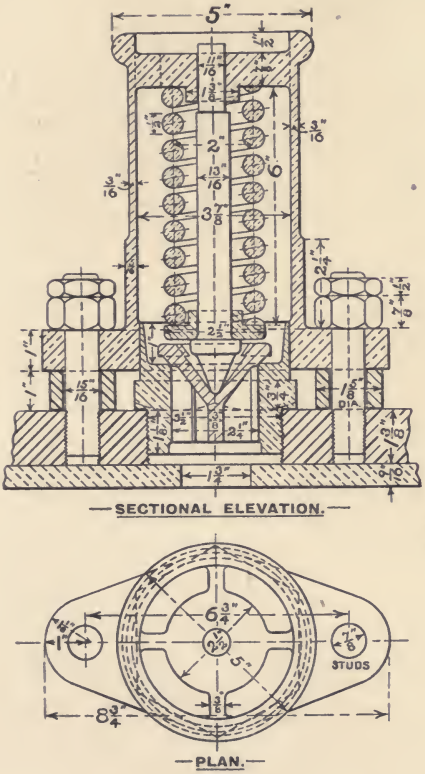


FIG. 2.

The two larger valves, Fig. 1. (opposite page) are loaded by means of a crossbar or lever, and one central spring, in tension. This type of valve is generally known as the "Ramsbottom." The working pressure is 220 lbs. per square inch, and the total load on the valves is 3375 lbs.

The smaller independent valve, Fig. 2, is loaded directly by a spring in compression, and this valve is set to "blow-off" at a slightly higher pressure than the main valves. The load on this valve is 875 lbs.

The object of this additional valve is to act as a tell-tale and also to assist in preventing the accumulation of pressure which occurs when an engine, running at full power, is unexpectedly stopped by a signal.

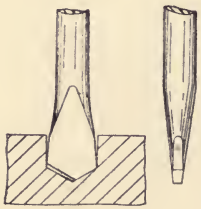
Supplied by

Mr. R. M. DEELEY, M.I.M.E.,

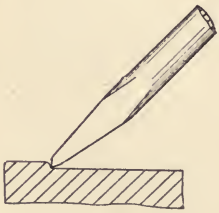
Late Chief Engineer, DERBY.

MACHINE TOOL DETAILS.

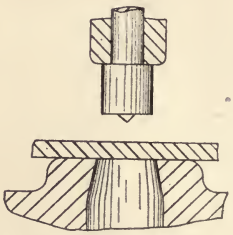
Give sketches showing examples of (1) Drilling, (2) Chipping, (3) Punching, (4) Slotting, (5) Planing, (6) Boring, (7) Milling, (8) Chasing, (9) Turning, (10) Screw-cutting, and (11) Facing.



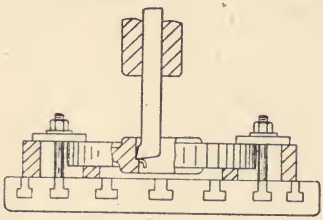
(1) DRILLING.



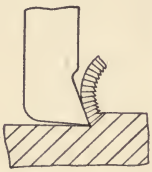
(2) CHIPPING.



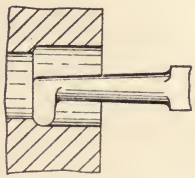
(3) PUNCHING.



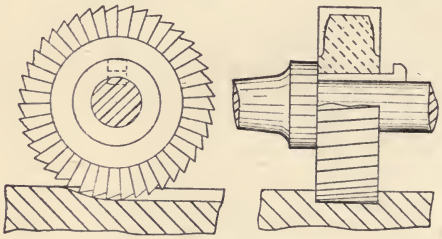
(4) SLOTTING.



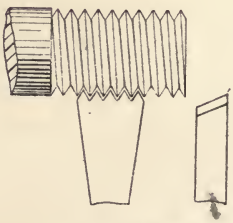
(5) PLANING.



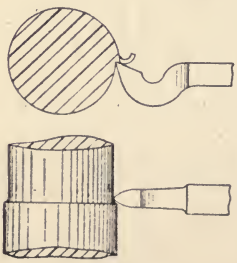
(6) BORING.



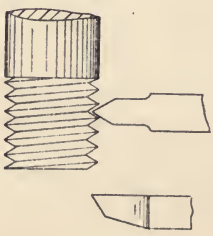
(7) MILLING.



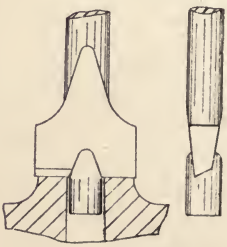
(8) CHASING.



(9) TURNING.

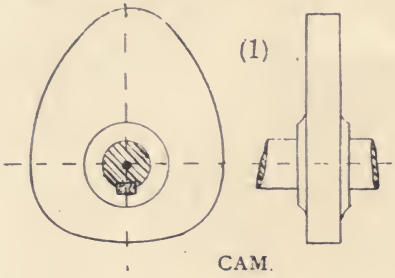


(10) SCREW CUTTING.

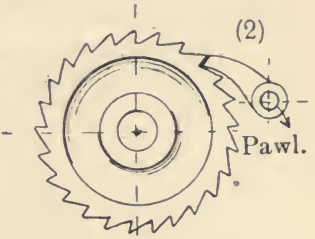


(11) FACING.

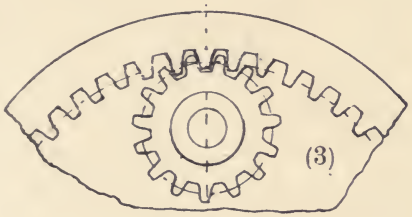
Make sketches showing the construction of (1) a Cam. (2) Ratchet Wheel and Pawl. (3) Invert Wheel. (4) Chain Wheel. (5) Rack and Pinion. (6) Worm and Wheel, the worm to run in an oil bath.



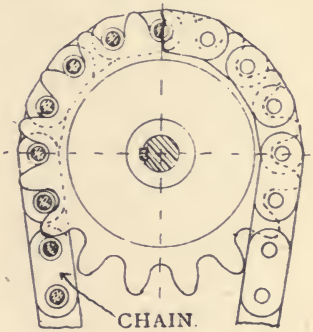
CAM.



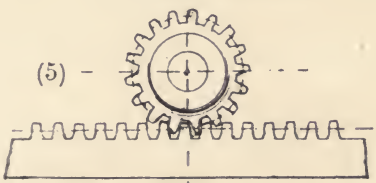
RATCHET WHEEL.



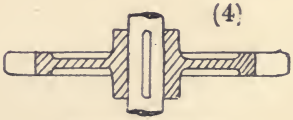
INVERT WHEEL.



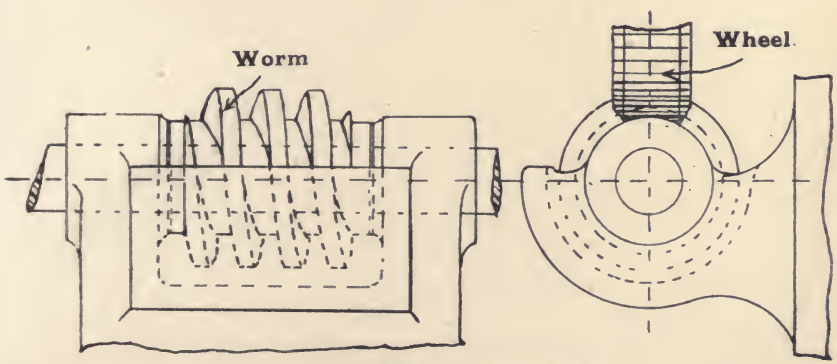
CHAIN.



RACK AND PINION.



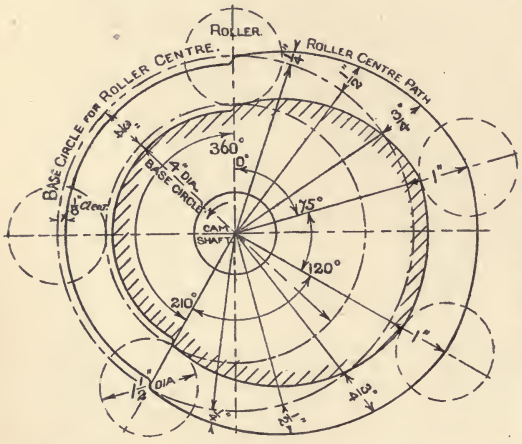
CHAIN WHEEL.



Bath Lubricator.

— THE DESIGN OF CAMS. —

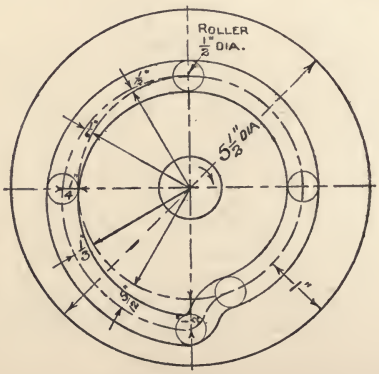
Design an Edge Cam to uniformly lift a rod up to 1″ from 0° to 75° of the cam shaft revolution; maintain the rod in this position from 75° to 120°; allow the rod to uniformly return to its normal position, from 120° to 210°, and remain in this position with $\frac{1}{8}$″ clearance between the cam and roller, from 210° to 360°. The roller attached to the rod is $1\frac{1}{2}$″ dia., and vertical above the centre line of the cam shaft. The base circle of the cam is 4″ dia. The direction of rotation is anti-clockwise.

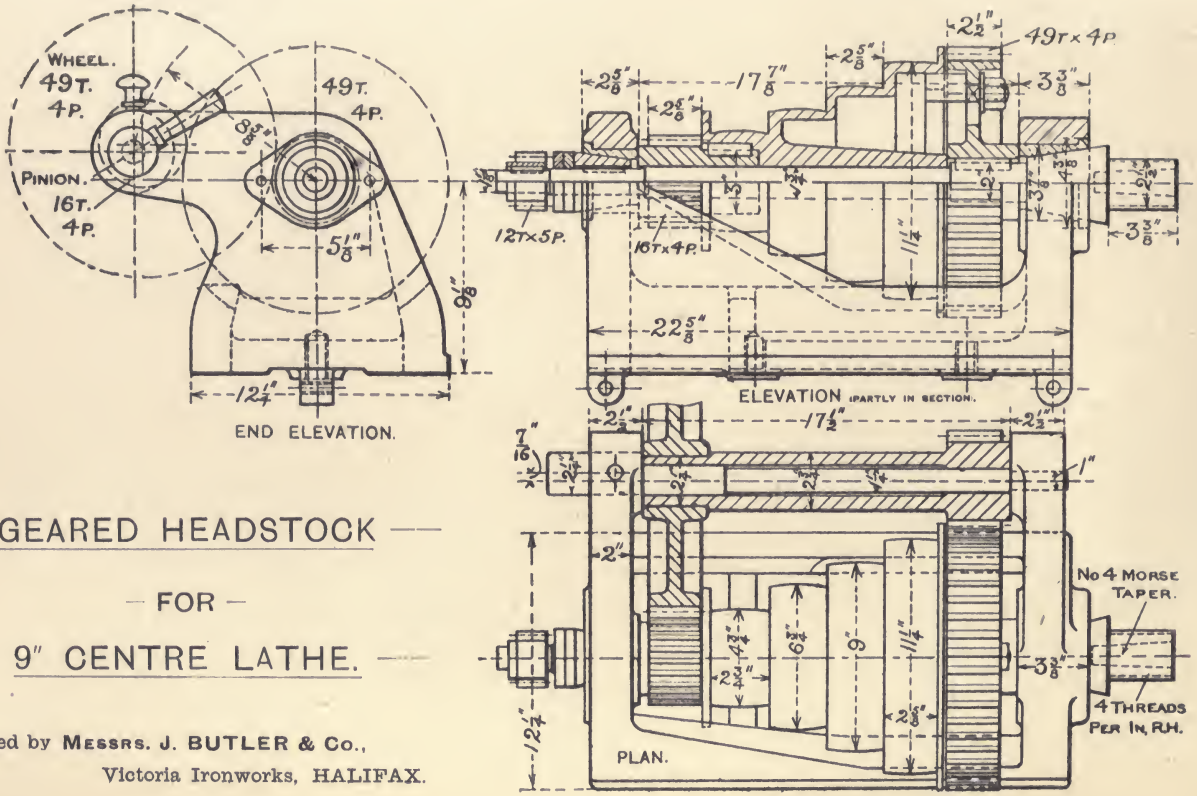


Set out the base circles for the cam and the roller centre. Mark the various angles. Divide the first 75° into four equal angles, and measure $\frac{1}{4}$″, $\frac{1}{2}$″, $\frac{3}{4}$″, and 1″ on the lines radiating from the centre, outside the outer base circle. If the points are joined a uniform lift up to 1″ will be obtained. From 75° to 120° the curve is circular. From 120° to 210°, set out similar to the first angle, but reducing the distance a $\frac{1}{4}$″ each time down to 0. From 210° to 360° the curve is circular with $\frac{1}{8}$″ clearance. This will complete the path of the roller centre, and if $1\frac{1}{2}$″ dia. circles are drawn on same, the line which touches their circumferences on the inside is the edge of the cam required.

Design a Face Cam to uniformly raise a link up to $\frac{1}{2}$″ during the first half of the cam shaft revolution, and then to allow the link to return instantly to its normal position and remain there during the remainder of the revolution. The outside dia. of the cam plate is $5\frac{1}{2}$″, the base circle for the centre of the roller is $3\frac{1}{2}$″ dia., and the roller $\frac{1}{2}$″ dia. The link is held vertically above the centre line of the cam shaft, which rotates in a clockwise direction.

Set out the cam plate and the base circle for the roller centre. Divide the left hand half of the circle into six equal angles, and mark outside the base circle on the radiating lines, distances increasing uniformly to $\frac{1}{2}$″, and join the points. The roller centre follows the base circle on the right hand half of the cam. Draw $\frac{1}{2}$″ circles on the roller centre path, and curves drawn to touch the circumferences on the inside, and outside will give the correct shape of the slot to be cut in the cam plate.





GEARED HEADSTOCK

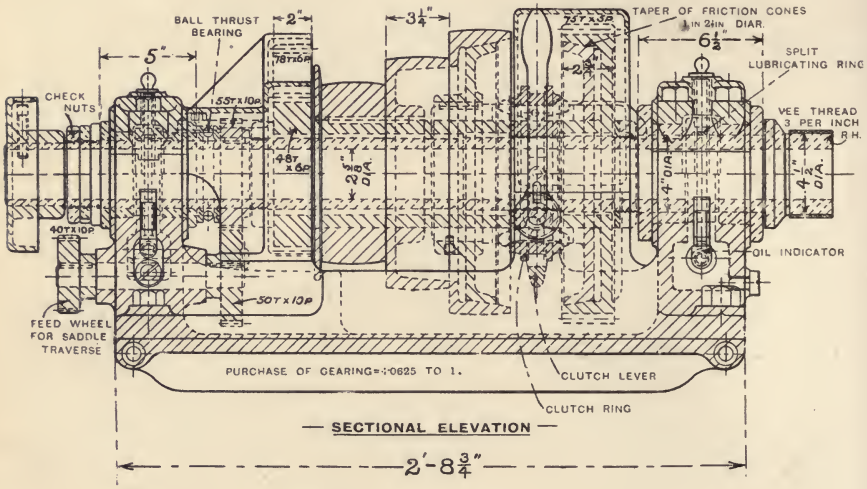
— FOR —

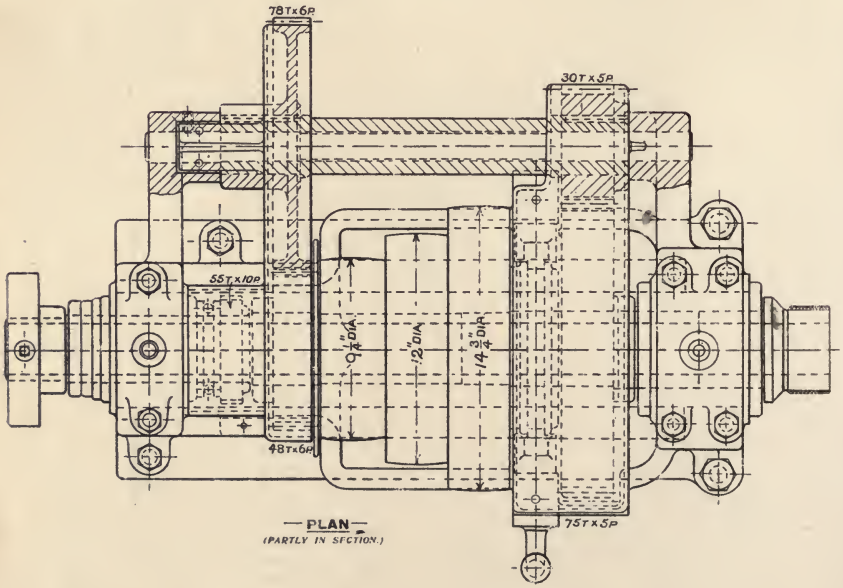
9" CENTRE LATHE.

Supplied by **MESSRS. J. BUTLER & Co.,**
Victoria Ironworks, HALIFAX.

— DRIVING HEADSTOCK. —

FOR 8½" CENTRE BORING AND REAMERING LATHE.





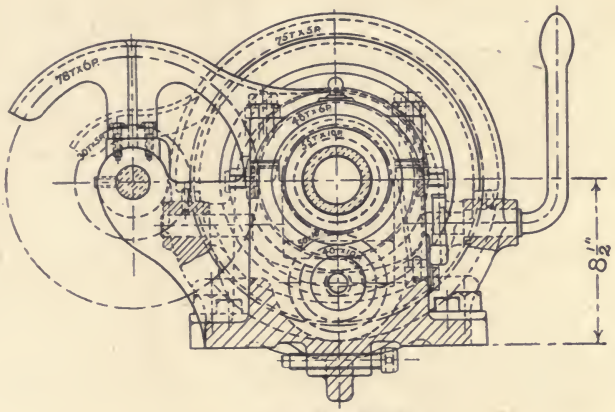
Supplied by

Messrs GREENWOOD & BATLEY, Limited,

Albion Works, LEEDS.

— DRIVING HEADSTOCK. —

FOR 8½" CENTRE BORING AND REAMERING LATHE.



— END ELEVATION —

The Driving Headstock for 8½" centre Capstan Boring and Reamering Lathe shown above, and on the opposite page, has a hollow steel spindle capable of taking a stock bar up to 2½" diameter. This spindle runs in parallel gun metal bearings which are fitted with self oiling rings working in oil baths. The spindle nose is threaded to receive the gripping chuck, and ball thrust washers are provided to take the end pressure.

The driving cone has three steps 9¼", 12" and 14¾" diameter respectively by 3¼" wide, it runs loose on the spindle and is connected by double purchase gearing (4·0625 to 1) to a large spur wheel which also runs loose on the spindle. Between the cone and the spur wheel, and engaging with *either*, are placed friction cones of large diameter actuated from the front of the headstock by a hand lever, through a toggle arrangement which is self locking. With the lever in the central position, the spindle is stationary, but a movement of the lever to the right or left brings the friction cone into driving contact with either the spur wheel or the driving cone, thus giving a slow or quick speed to the spindle.

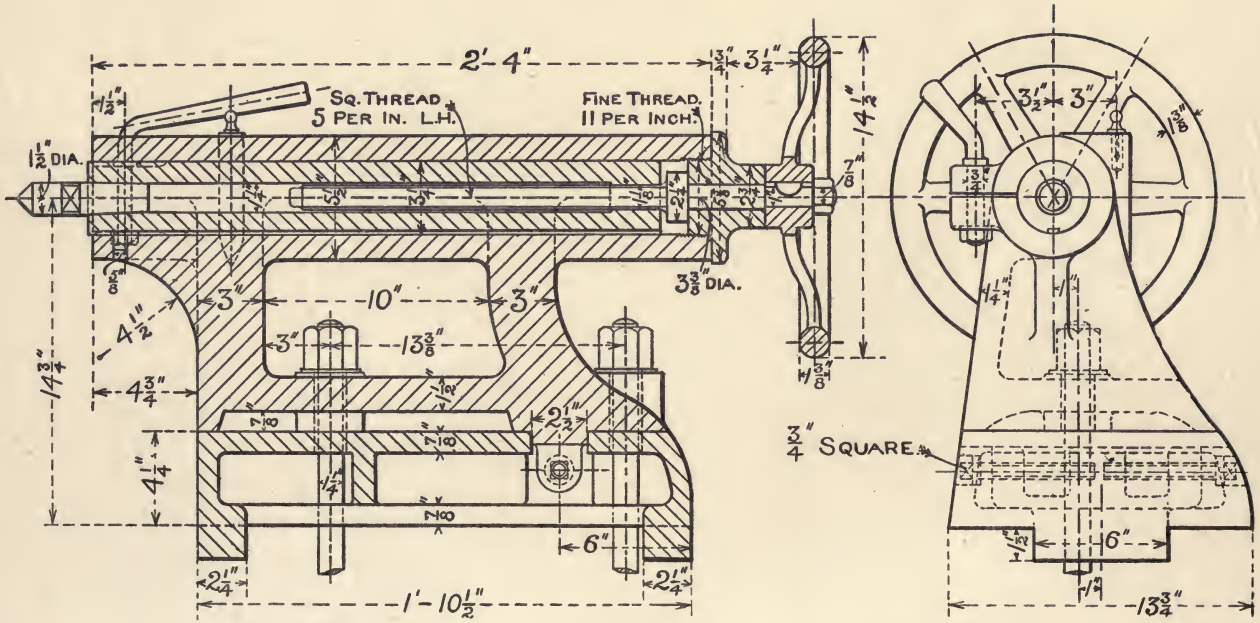
Threaded collars and pressure plates are provided for adjusting the friction cones, and also for confining to the spindle the end pressure due to the application of the clutch. The countershaft is arranged to run at two speeds, viz:—150 and 190 revs. per minute, so that, altogether, the spindle has 12 rates of speed varying in geometrical progression from 24 to 300 revs. per minute.

Supplied by

Messrs. GREENWOOD & BATLEY, Limited,

Albion Works, LEEDS.

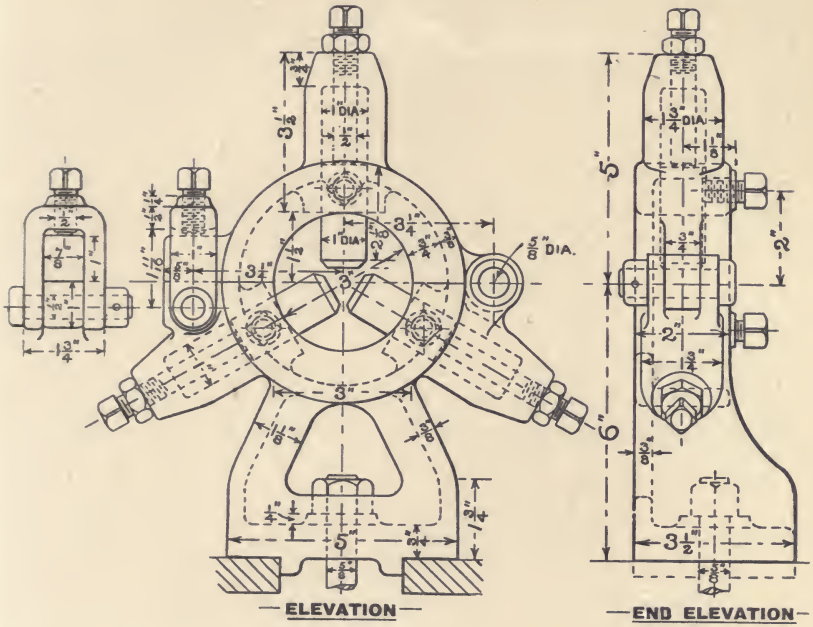
— LOOSE HEADSTOCK FOR 14½" CENTRE LATHE. —



Supplied by Messrs. C. REDMAN & SONS, Pioneer Ironworks, HALIFAX.

STATIONARY STAY.

FOR 6" CENTRE HIGH SPEED LATHE.



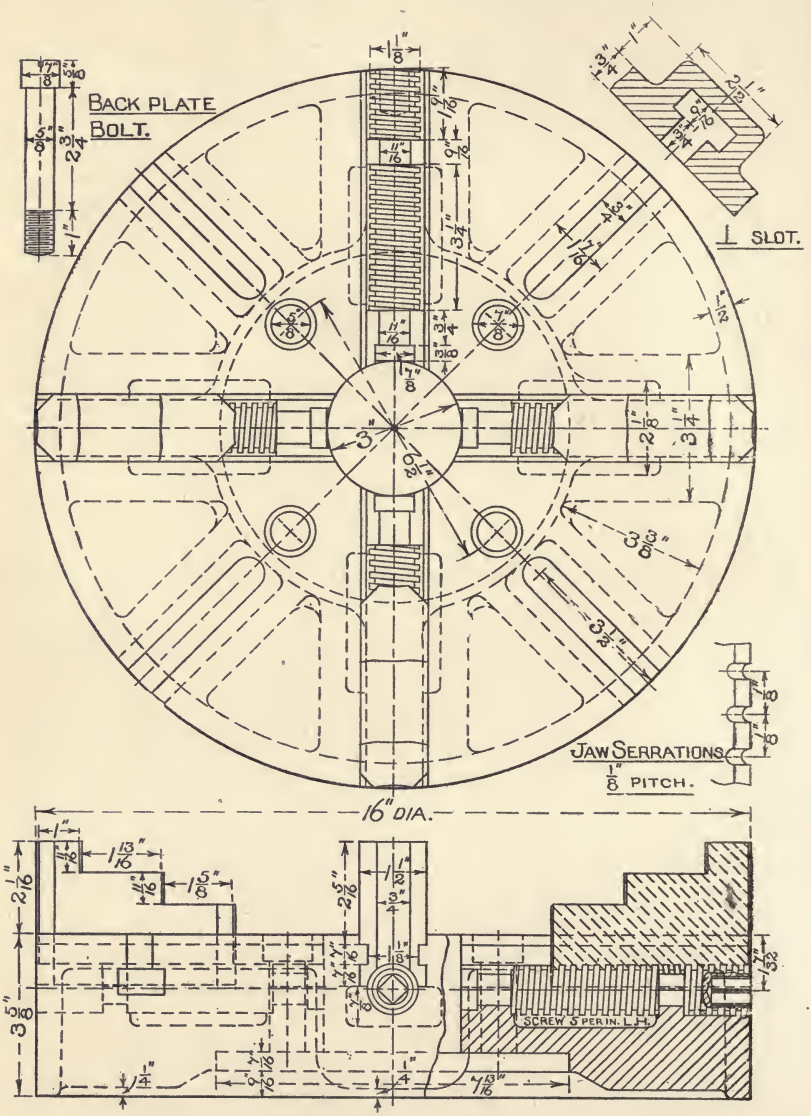
The Stationary Stay or steady rest shown above is for a 6" centre lathe. It is used as a support for long slim work, which, if unsupported would sag by its own weight, and thus cause an inaccurate piece of work. It is also used for supporting the front end of a shaft whilst being bored. the rear end of the shaft being held and driven by a chuck on the spindle nose of the headstock. The capacity of the stay is 3" diameter. The jaws are of brass and are circular, which is an improvement on the old style of flat jaws. The jaws are first adjusted to the work by the square head screws, then the checknuts are locked to keep the screws fixed and the jaws clamped by means of the three screws at the rear. Suitable flats are provided on the jaws for these screws to nip against.

The top part of the stay is hinged so that it may be lifted back for convenience in placing and removing the work. The stay is clamped to the lathe bed by a $\frac{5}{8}$" diameter bolt as shown. The body of the stay is of cast iron, and the nuts and screws mild steel.

Supplied by
Messrs. D. MITCHELL & CO., Limited,
Central Ironworks, KEIGHLEY.

FOUR JAW CHUCK.

WITH INDEPENDENT AND REVERSIBLE JAWS.

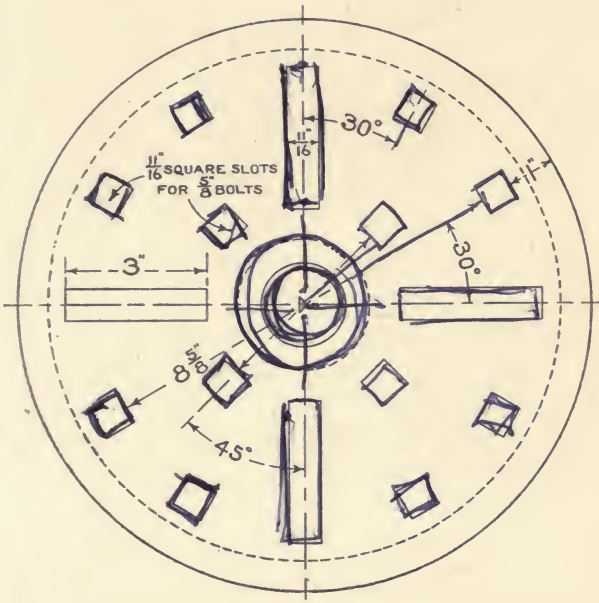


THE SCREWS HAVE DOUBLE THRUST BEARINGS.

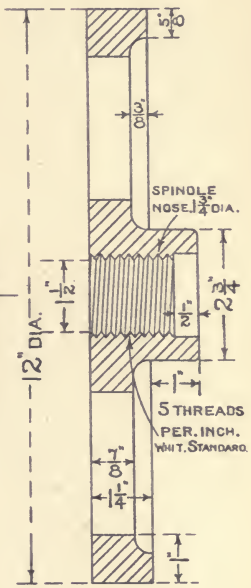
Supplied by
Messrs. F. PRATT & CO., Limited,
Eagle Ironworks, HALIFAX.

FACEPLATE.

The Faceplate shown is suitable for a 6″ centre straight bed lathe. The spindle nose is screwed five threads per inch, right hand; the thread appears left hand in the hole. The inner end of the spindle nose is left plain, on to which the faceplate fits. This plain part also relieves the screw threads of some of the thrust.



FRONT ELEVATION.



SECTIONAL ELEVATION.

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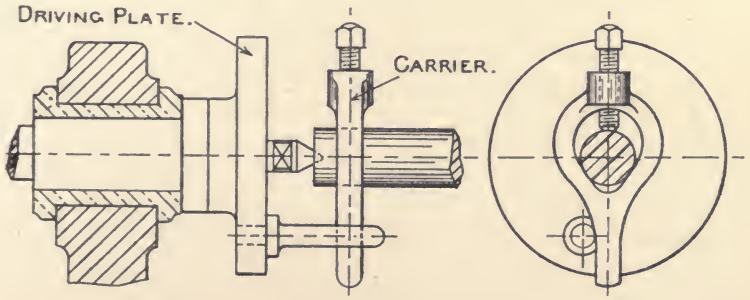
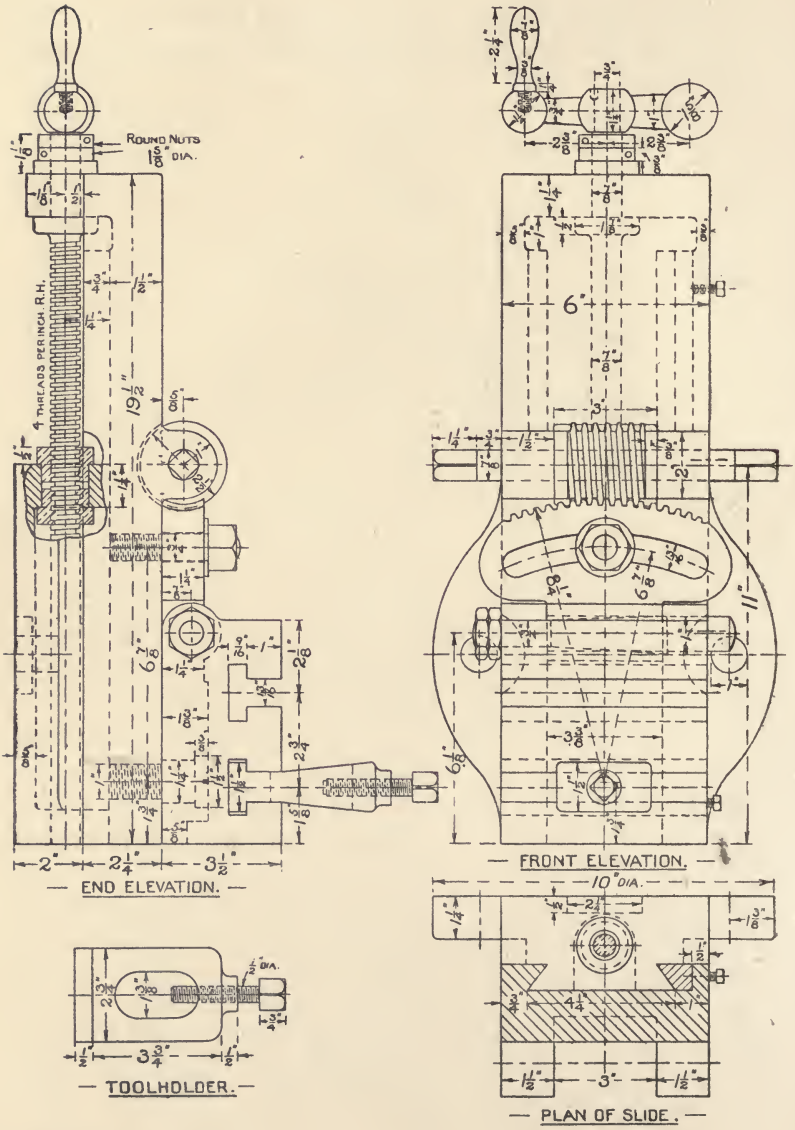
*Give sketches showing how you would grip and drive a round iron bar for the purpose of turning it between the centres of a lathe. (130)



— TOOL BOX. —

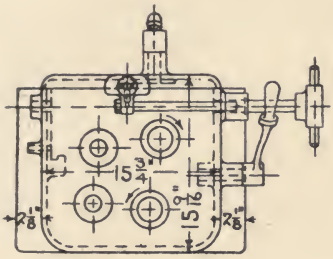
FOR 18" STROKE SHAPING MACHINE.



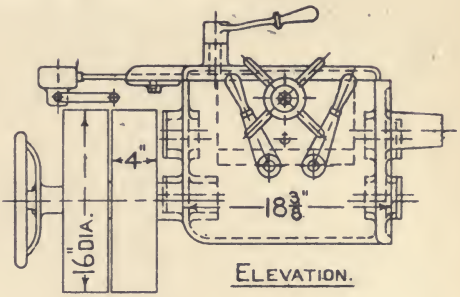
Supplied by
Messrs. HENRY HOLMES & CO.,
Central Ironworks. HALIFAX.

— 12 SPEED GEAR BOX. —

FOR HIGH SPEED RADIAL DRILLING MACHINE.



END ELEVATION
(PULLEYS REMOVED)

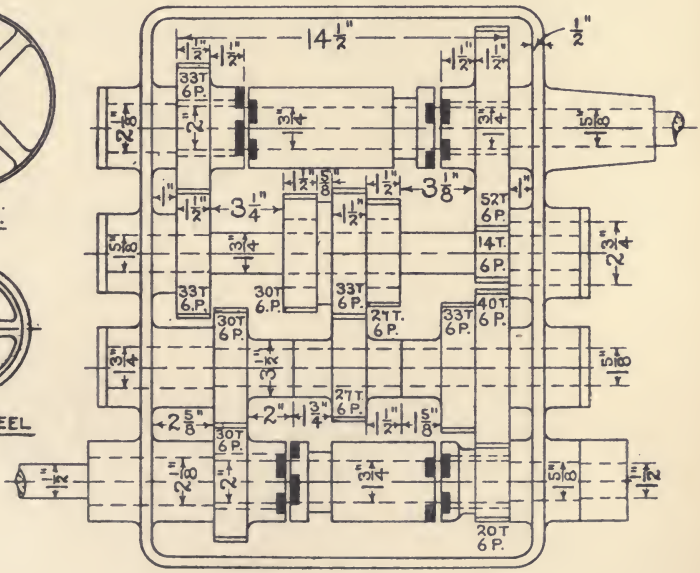


ELEVATION.

310 R.P.M.

PULLEY.

HANDWHEEL

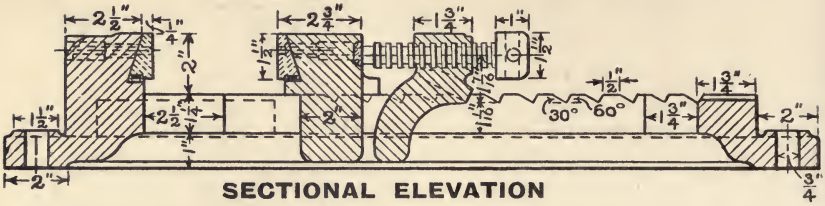


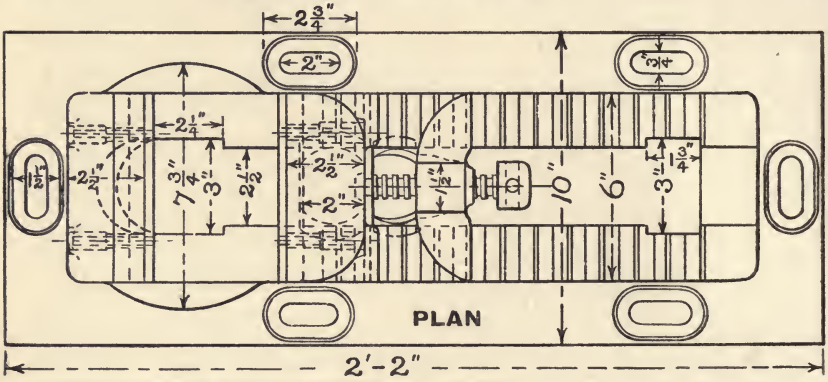
PLAN OF GEARS.

In the plan view, all the four shafts are drawn in the same plane, in order to show the gears clearly. The end elevation shows the true positions of these shafts. The top shaft, which drives the machine, will give the following revolutions per minute, viz:—34, 42, 51, 68, 83, 102, 127, 155, 189, 254, 310 and 379, when the driving pulleys make 310 revolutions per minute.

Supplied by
Messrs. GEORGE SWIFT & SONS, Limited,
Claremont Ironworks, HALIFAX.

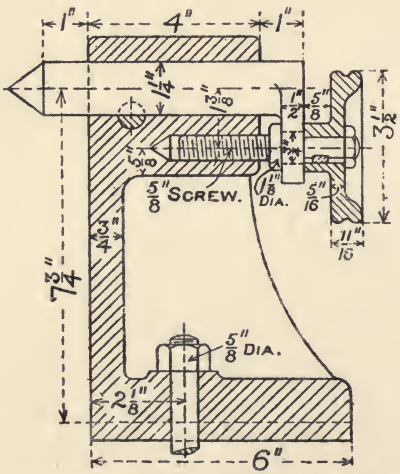
— 6″ QUICK ACTION MACHINE VICE. —



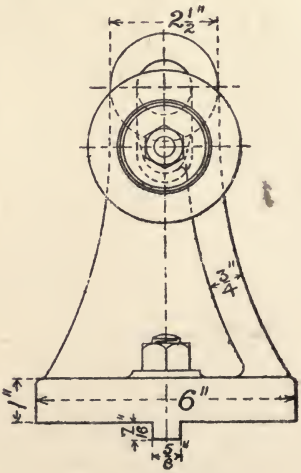


— LOOSE HEAD. —

As used in the Dividing Heads for cutting Spur and Bevel Gears up to 15″ Dia.



Sectional Elevation.

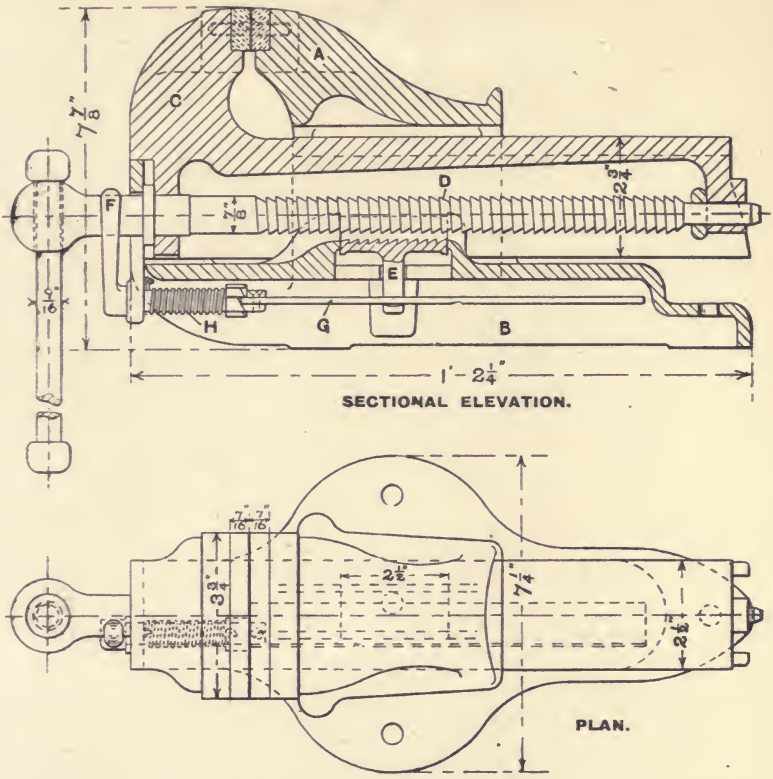


End Elevation.

Supplied by
Messrs. SMITH & COVENTRY, Limited,
Gresley Ironworks, MANCHESTER.

— PARKINSON'S "PERFECT" VISE. —

MODEL F.



In the improved type of "Perfect" Vise shown above, the fixed jaw A is cast in one piece with the base B and embraces the sliding jaw C. The latter carries a buttress thread screw D, fitting a half nut E lying in a recess in B.

The screw, or the instantaneous action, is alternatively brought into operation as desired, according to whether the nut E is lowered out of mesh with the screw D (as seen), or whether it is raised up to engage. In the first case the jaw C may be slid freely to and fro; in the second it can be moved only by turning the screw by the long handle, acting then as an ordinary screw vise. The movement of E is produced by the lever F, which when clasped by the hand to the knob of the screw D, turns the flat strip G lying in a groove in E and lowers the latter. When F is released the spring H draws it outwards, pressing E upwards, so that in the normal state the vise remains a screw one.

Supplied by

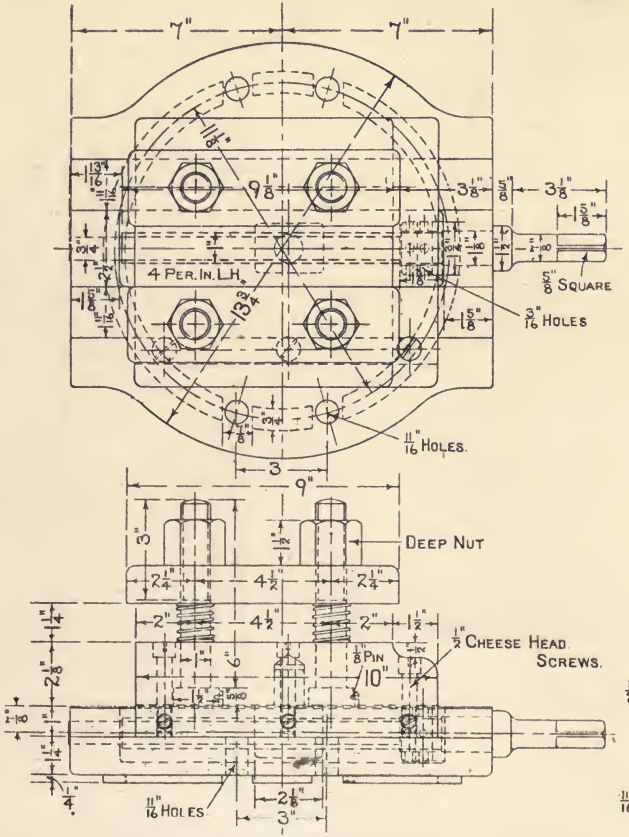
Messrs. J. PARKINSON & SON,

Canal Ironworks, SHIPLEY, Yorks.

SLIDE REST.

FOR 10" CENTRE LATHE.

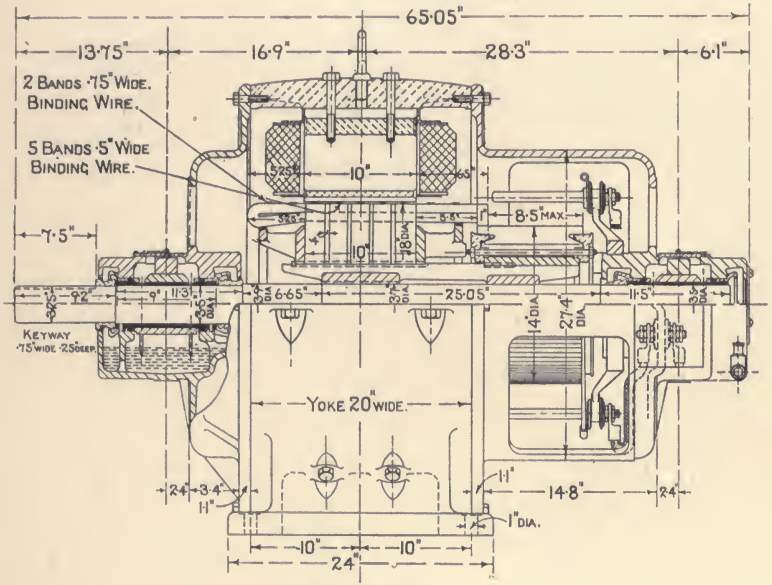
Supplied by
Messrs. JOHN STIRK & SONS, Limited,
Machine Tool Makers, HALIFAX.



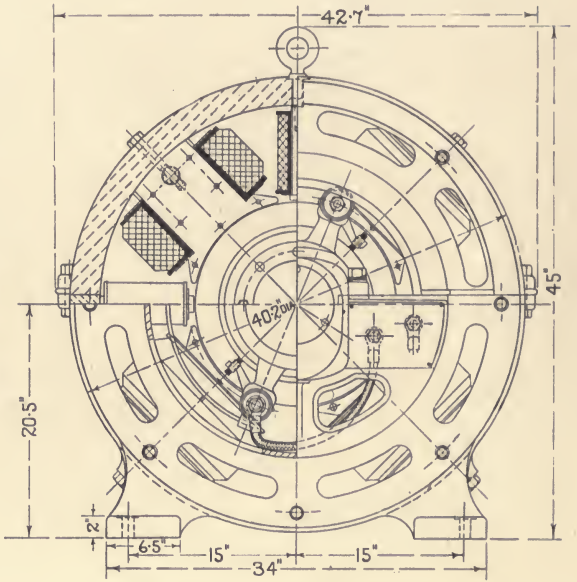
— VICKERS' "F" TYPE STANDARD SHUNT WOUND MOTOR. —

FOR VARIABLE SPEEDS AND DIRECT CURRENT SUPPLY.

This type of motor is fitted with interpoles, and will give 38 to 60 B H.P. at voltages of either 220 or 440. When the B.H.P. is 50, the speeds vary from 275 to 825 revolutions per minute.



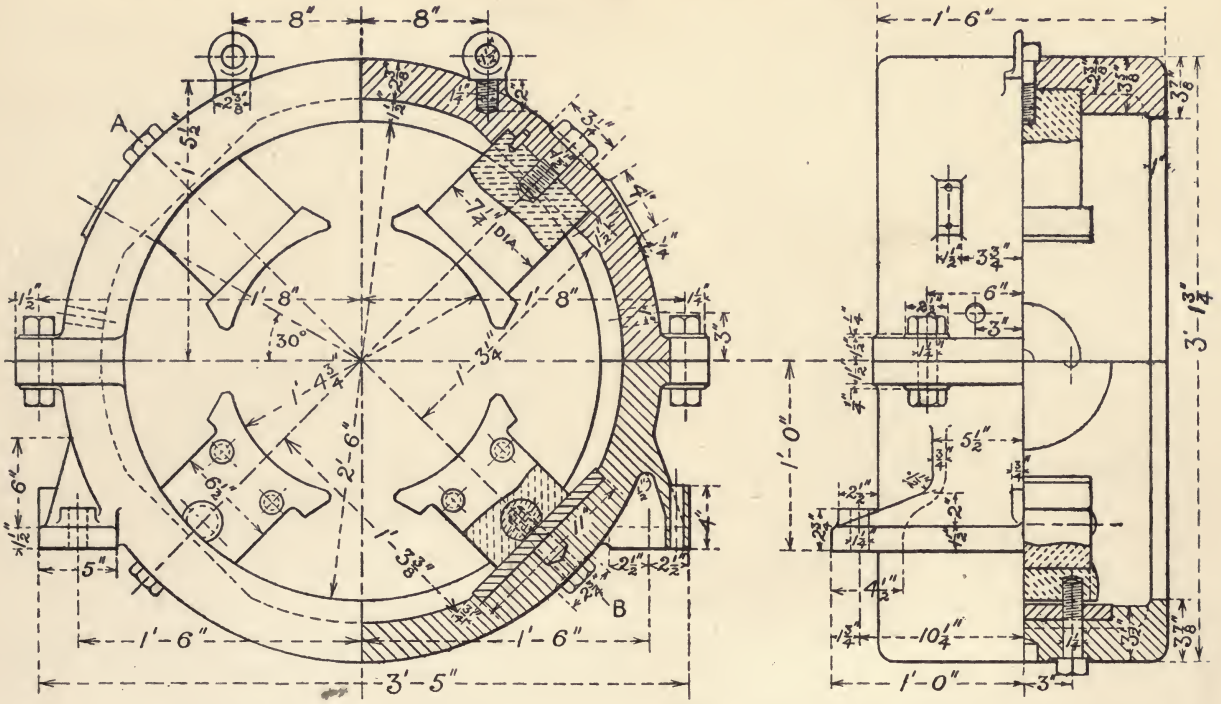
ELEVATION. (Half in Section).



END ELEVATION (Partly in Section.)

Supplied by Messrs. VICKERS, Limited,
River Don Works, SHEFFIELD, and Broadway, LONDON, S.W.

55 KILOWATT DYNAMO, DETAILS OF FIELD MAGNETS.



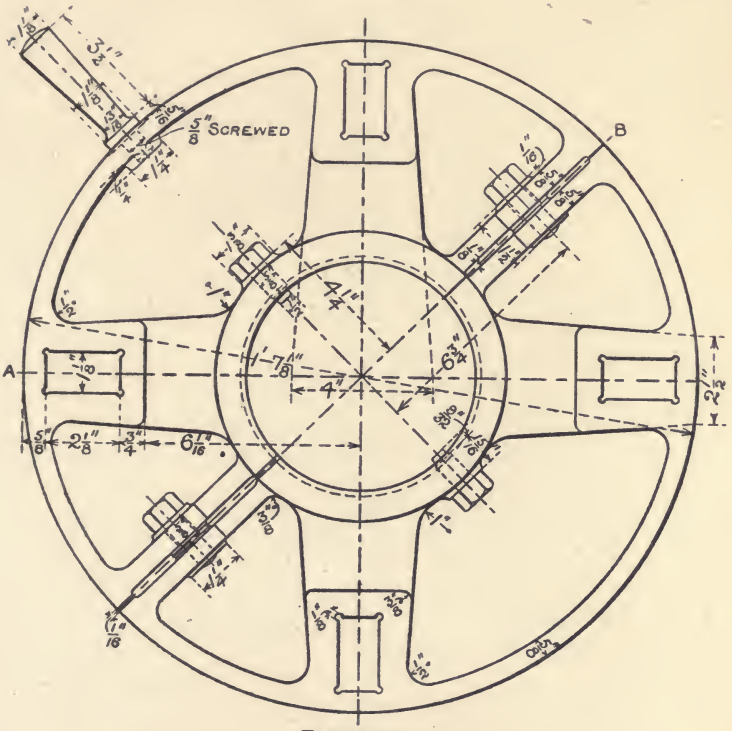
ELEVATION (Partly in Section).

END ELEVATION (Partly in Section at A.B.)

Supplied by Messrs. WRIGHT & WOOD, Limited, Electrical Engineers, HALIFAX.

DETAILS OF BRUSH ROCKER.

FOR STANDARD TYPE DYNAMO.



Supplied by

Messrs. WRIGHT & WOOD, Limited,

Electrical Engineers, HALIFAX.

NOTE.—For Electrical Terms refer to the Author's Book "Practical Workshop Mechanics;" and for examples of electrically driven machine tools see "Bentley's Machine Shop Companion."

"SCOTT & MOUNTAIN."

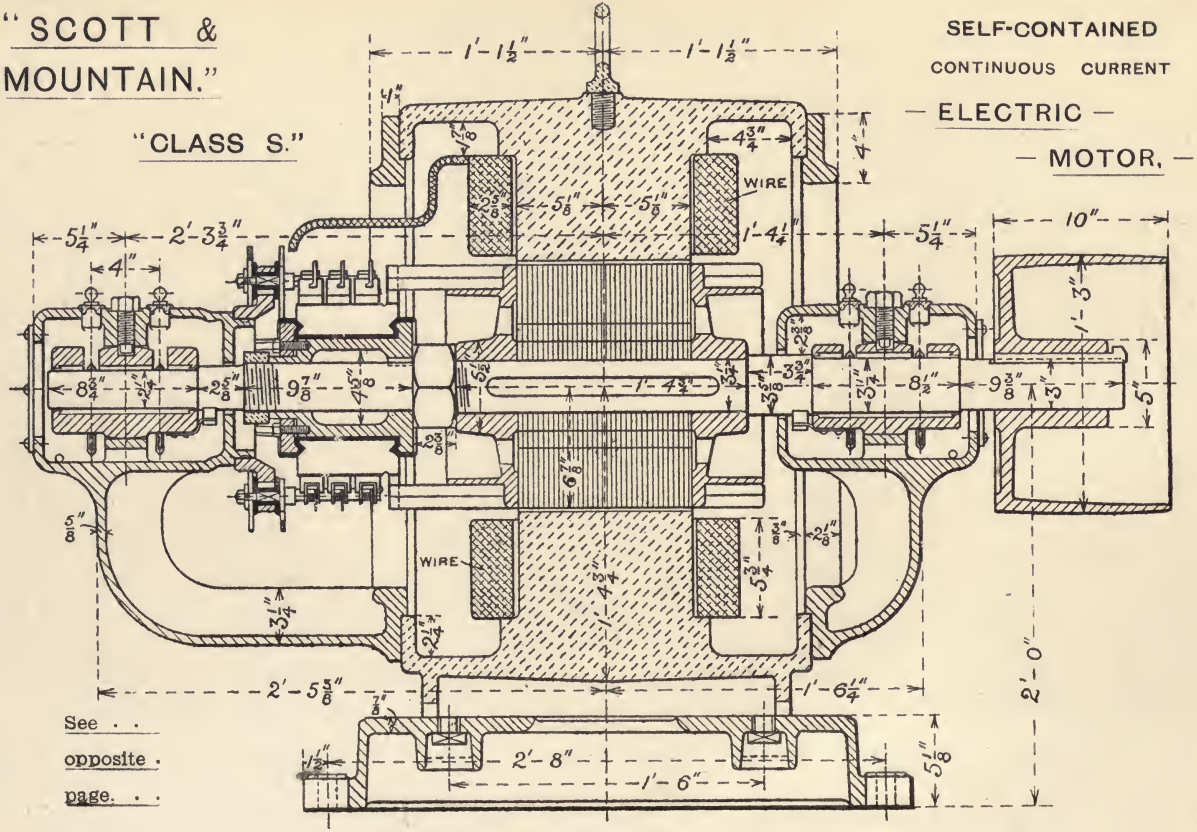
"CLASS S."

SELF-CONTAINED

CONTINUOUS CURRENT

— ELECTRIC —

— MOTOR. —

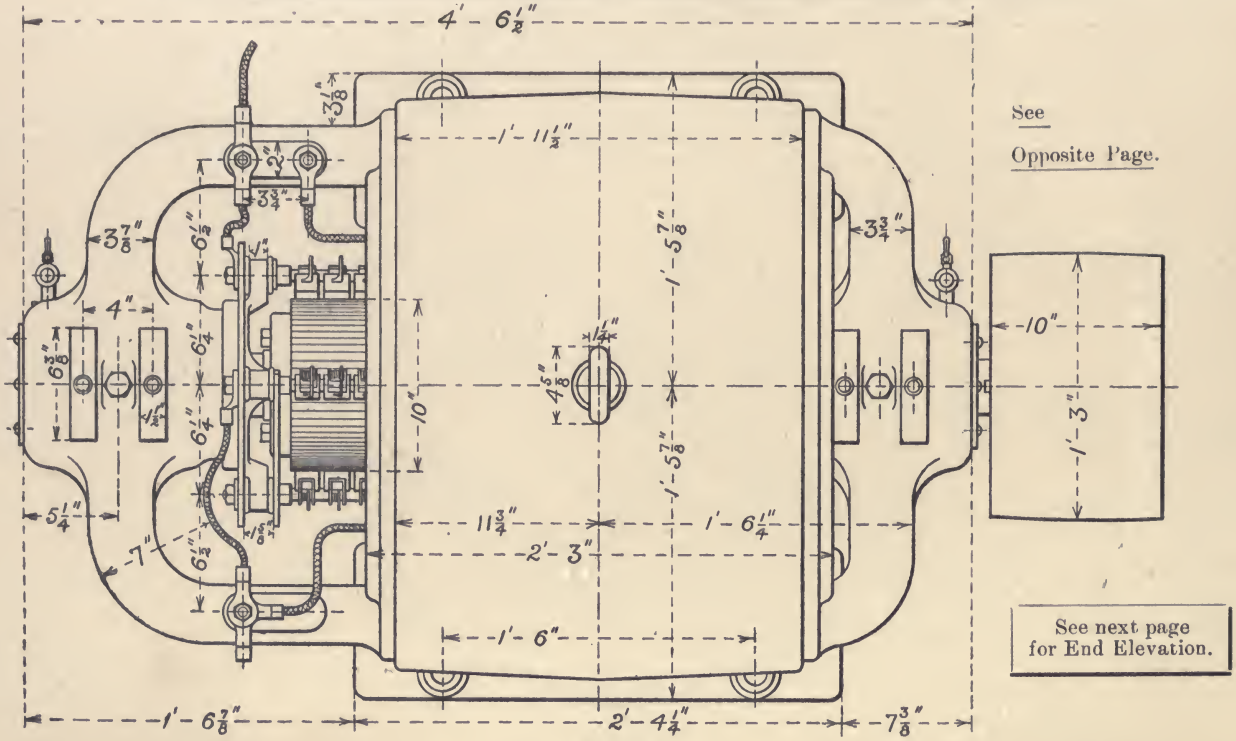


— Sectional Elevation. —

See . . opposite . page. . .

— "SCOTT & MOUNTAIN," CLASS S. —

SELF-CONTAINED CONTINUOUS CURRENT ELECTRIC MOTOR.



See Opposite Page.

See next page for End Elevation.

— PLAN. —

Supplied by Messrs. ERNEST SCOTT & MOUNTAIN, Limited. Electrical Engineers, NEWCASTLE-ON-TYNE

"SCOTT

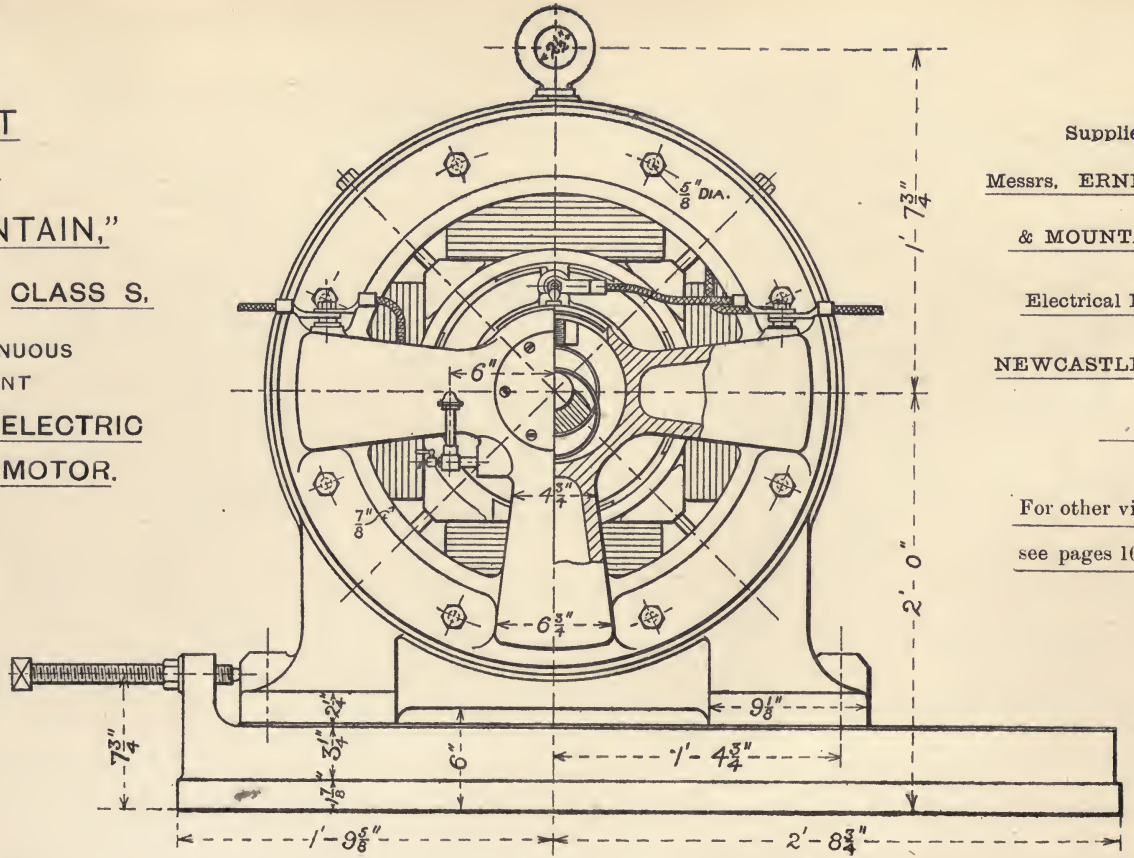
— & —

MOUNTAIN,"

CLASS S.

CONTINUOUS CURRENT

ELECTRIC MOTOR.



END ELEVATION.

Supplied by

Messrs. ERNEST SCOTT

& MOUNTAIN, Ltd.,

Electrical Engineers,

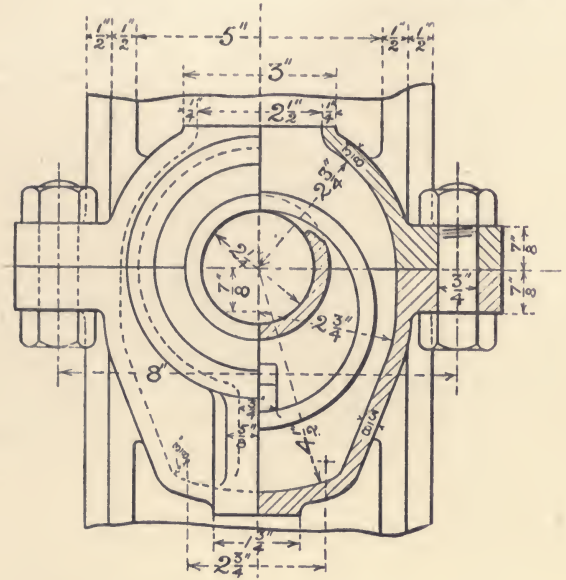
NEWCASTLE-ON-TYNE.

For other views

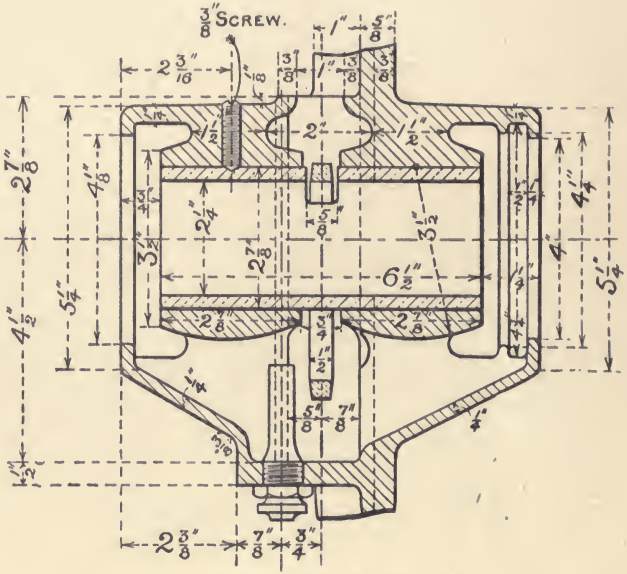
see pages 102 and 103.

MATHER & PLATT'S 'STEEL-CLAD ELECTRIC MOTOR."

DETAILS OF BEARING.



END ELEVATION (Partly in Section.)

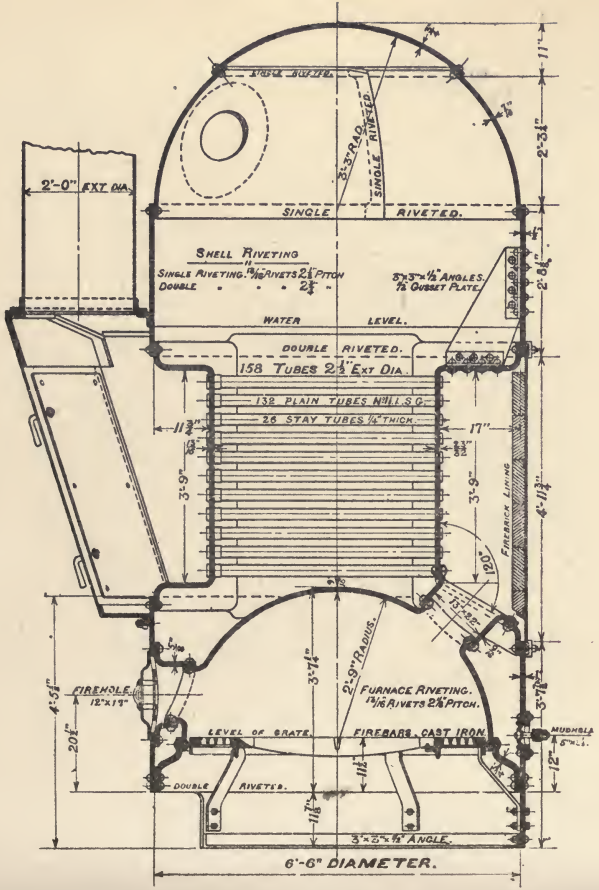


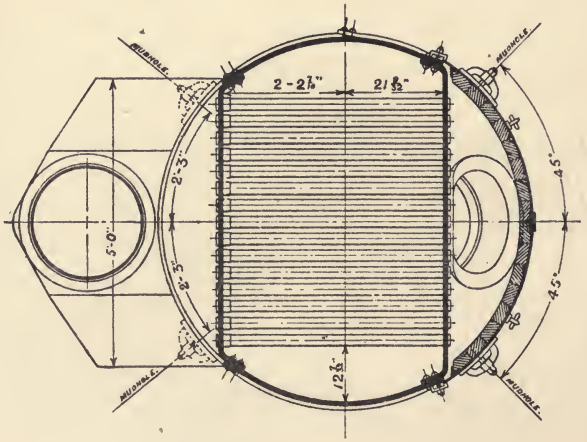
SECTIONAL ELEVATION.

Supplied by Messrs. MATHER & PLATT, Limited, Salford Iron Works, MANCHESTER.

COCHRAN'S

VERTICAL MULTITUBULAR BOILER.

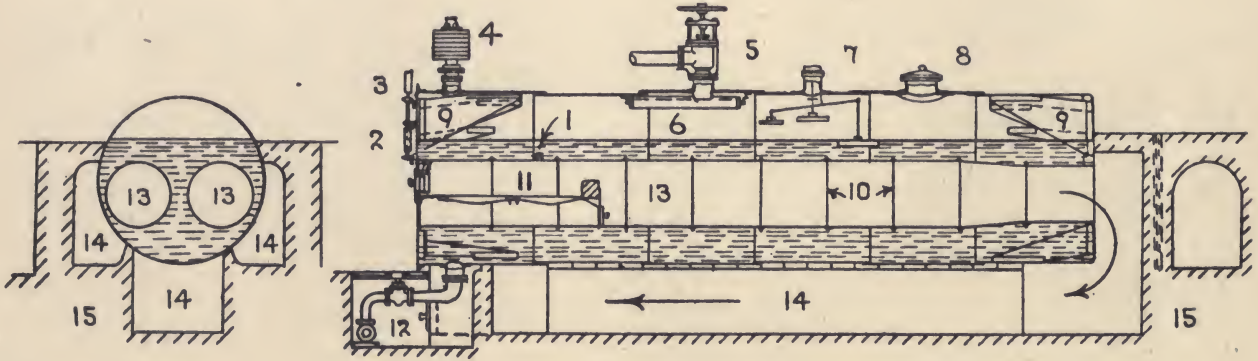




The drawings show a Cochran Vertical Multitubular Boiler 6′ 6″ in dia., and 14′ 6″ high, with a heating surface of 500 square feet, and a grate area of 22½ square feet. It is designed for a working pressure of 100 lbs per square inch, is tested by steam to that pressure, and by water to 200 lbs. per square inch. The tubes are of lap-welded iron, "B B" quality, and are tested hydraulically to 1,000 lbs. per square inch. All plates are of Siemen's Martin mild steel and are tested by Lloyd's Surveyors. Those exposed to flame, or flanged, have a tensile strength of 26 to 30 tons per square inch, elongation 23% in 8 inches; those not so exposed, 28 to 32 tons, elongation 20% in 8 inches.

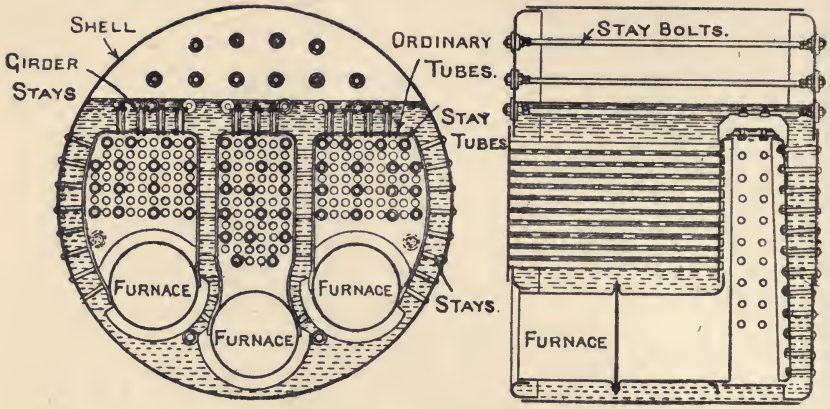
LANCASHIRE BOILER.

The Lancashire Boiler usually varies from 5′ 6″ dia. up to 8′ 6″ dia., and from 15 feet to 30 feet in length. The Cornish Boiler is similar, but with one central furnace instead of two. Cornish Boilers range from 4′ 0″ to 7′ 0″ dia., and from 10 feet to 30 feet in length.



1. Fusible Plug.
2. Water Level Gauge.
3. Steam Pressure Gauge.
4. Dead Weight Safety Valve.
5. Main Stop Valve.
6. Steam Collecting Pipe.
7. High and Low Water Safety Valve.
8. Manhole.
9. Gusset Stay.
10. Adamson's Rings.
11. Firebars.
12. Blow-off Cock
13. Furnaces.
14. Flues.
15. Brickwork.

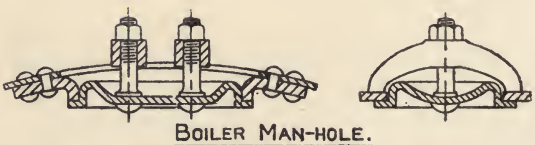
— MARINE BOILER. —



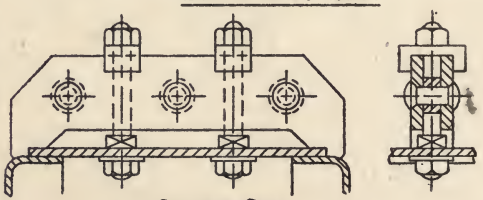
Single Ended Marine or Scotch Boilers up to 9 feet dia. have usually one furnace; from 9 feet to 12 feet dia., two furnaces; from 12 feet to 15 feet, three furnaces; and above 15 feet, four furnaces.

Give sketches showing (1) a Boiler Manhole, (2) a Girder Stay, (3) a Longitudinal Stay, (4) a Screwed Stay, as used in the construction of Steam Boilers.

Steam Boilers are fitted with **Manholes** in order that the interior of the boiler may be entered and examined. **The Girder Stay** is used for stiffening the roofs of Locomotive and Marine Boiler Fireboxes. **Longitudinal Stays** are employed to prevent the boiler ends from bulging, and **Screwed Stays** are used for stiffening the sides of the fireboxes in Locomotive and Marine Boilers. The hole drilled in the Screwed Stay, shown black, enables a broken stay to be readily located by allowing the water to escape through the end.



BOILER MAN-HOLE.

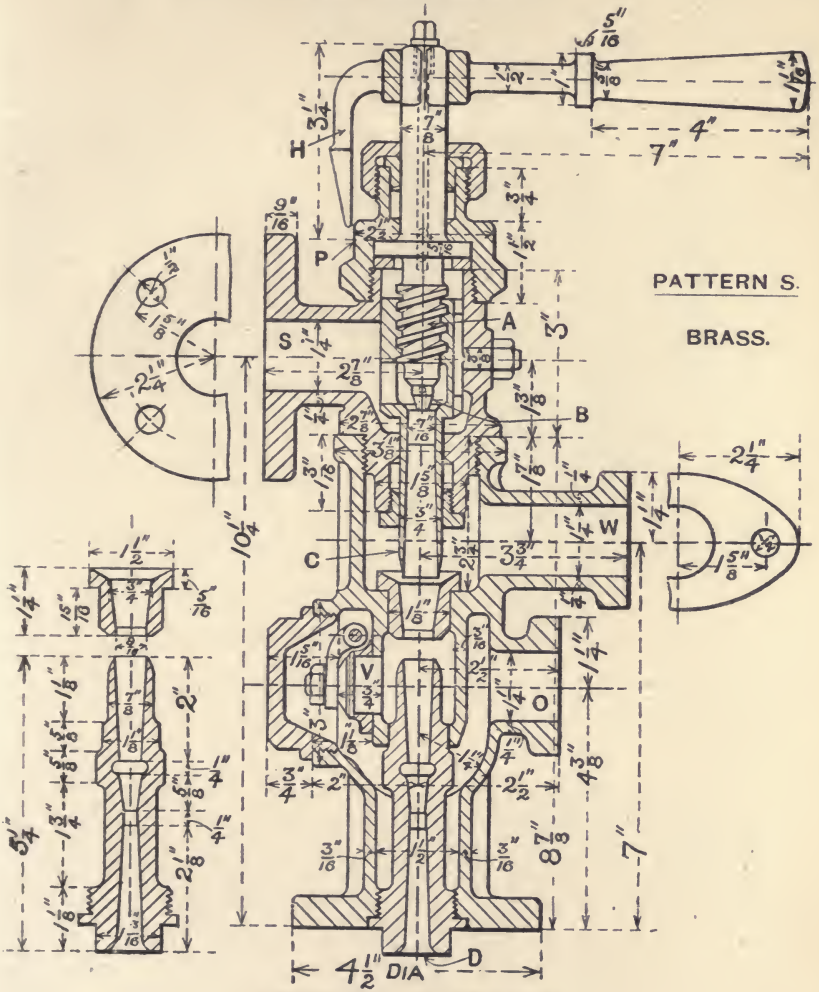


GIRDER STAY.

LONGITUDINAL STAY. SCREWED STAY.

— DETAILS OF THE "SIRIUS" INJECTOR. —

(ONE MOVEMENT.)



SECTIONAL ELEVATION.

— REFERENCE. —

A = Screwed Spindle controls Steam and Water Regulation.

B = Steam Regulating and Admission Valve. (open).

C = Movement of Pointer Advances or Withdraws Steam Cone, and Regulates Water Admission at this point.

D = Delivery Outlet.

H = Regulating Handle with Pointer.

O = Overflow Outlet.

P = Scale of Pressure on this Ring.

S = Steam Inlet.

V = Automatic Restarting Valve.

W = Water Inlet.

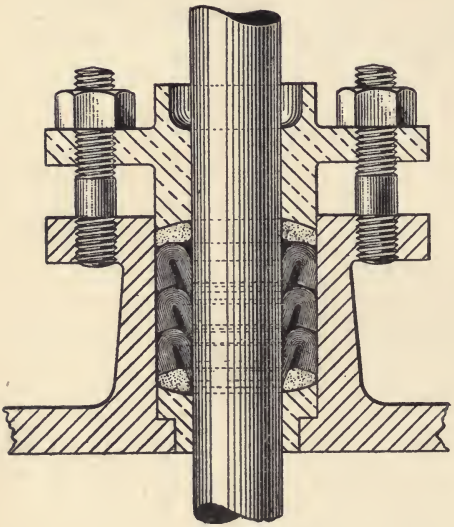
Supplied by

Messrs. HOLDEN & BROOKE, Limited,

"Sirius" Works, MANCHESTER.

— PUMP ROD PACKING. —

FOR THE R.M.S. "OLYMPIC," FITTED WITH S.E.A. RINGS.



The gland and stuffing box are of the usual type. The special feature is the form of the packing rings, which not only prevents leakage but keeps friction down to a minimum. For hydraulic purposes S.E.A. Rings are made from fine pure flax in the form shown in the drawing.

—

Supplied by

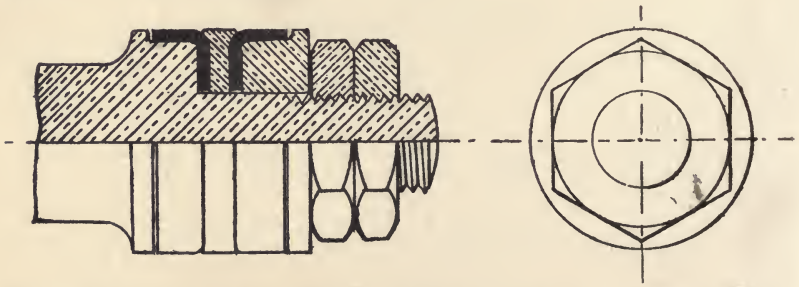
Messrs. RONALD TRIST & CO., Limited,

LONDON, E.C.

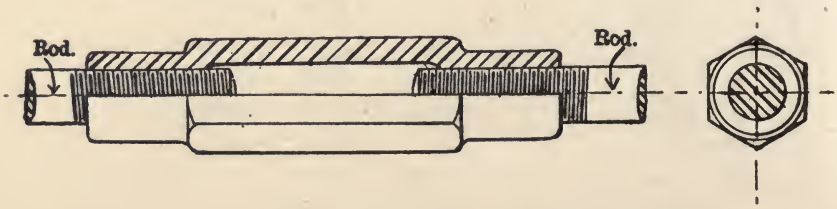
---

*Show by sketches the construction of an Hydraulic Piston suitable for high pressure.

(270)

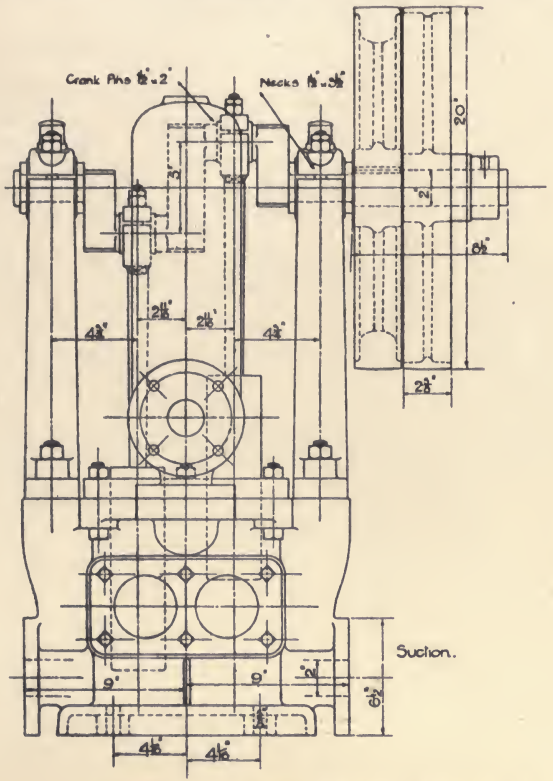


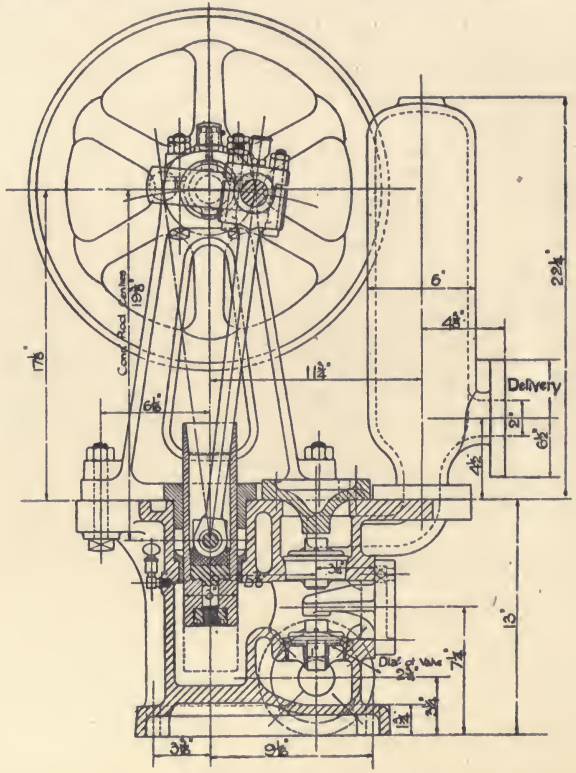
Make sketches of an Adjustable Joint suitable for connecting Valve and Pump Rods, etc.



PEARN'S DOUBLE RAM PUMP.

RAMS 3" DIA. STROKE 5" CAPACITY 1340 GALLONS PER HOUR. FOR 140 FEET HEAD

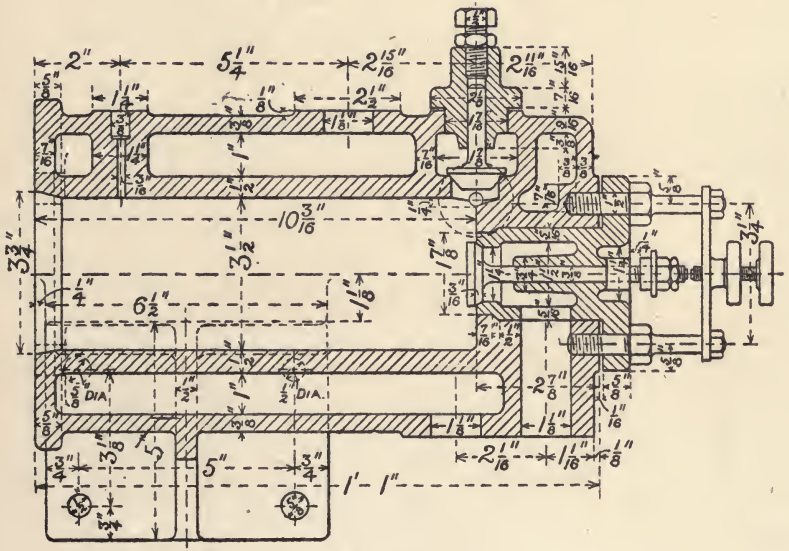




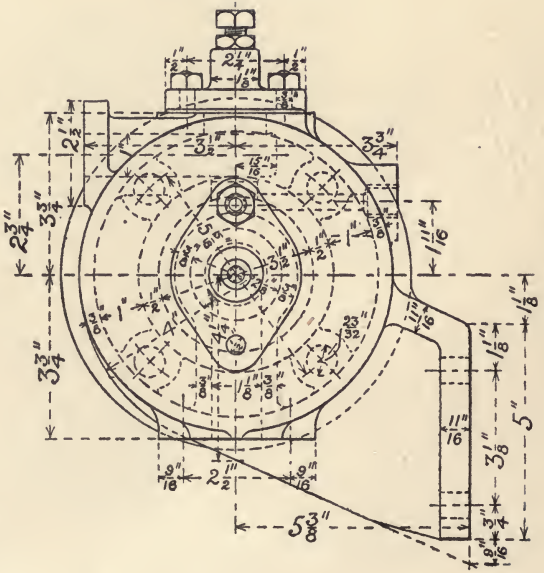
Supplied by Messrs. FRANK PEARN & CO., Limited, West Gorton, MANCHESTER.

— DETAILS OF SINGLE ACTING "AIR COMPRESSOR." —

CYLINDER 3½" DIA × 6" STROKE.



— SECTIONAL ELEVATION. —

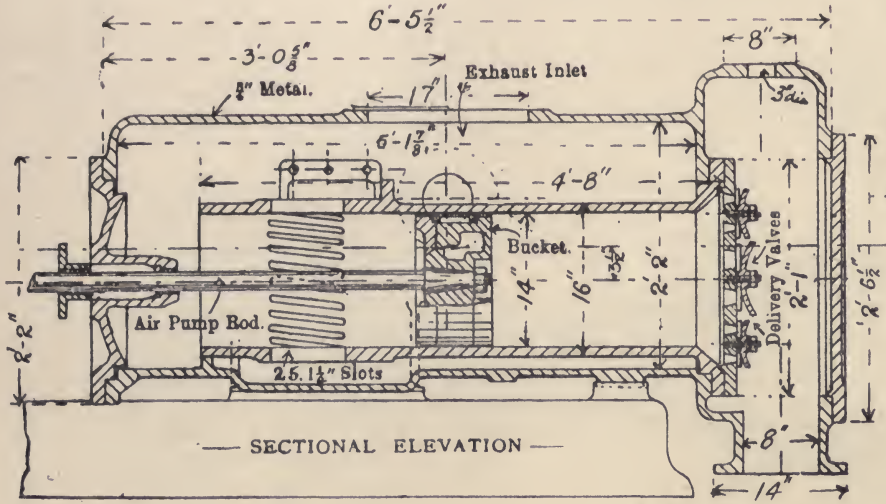


— END ELEVATION. —

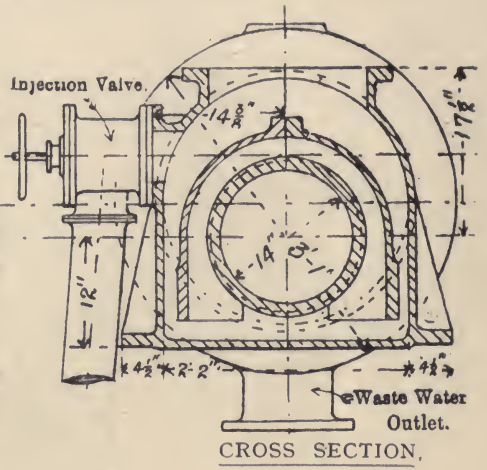
Supplied by Messrs. **THE CAMPBELL GAS ENGINE CO., Limited, HALIFAX.**

— 14IN. AIR PUMP AND CONDENSER, 4FT. STROKE. —

POLLIT & WIGZELL'S PATENT.



8 valves 4¼" diameter.
1 valve 6⅝" diameter.



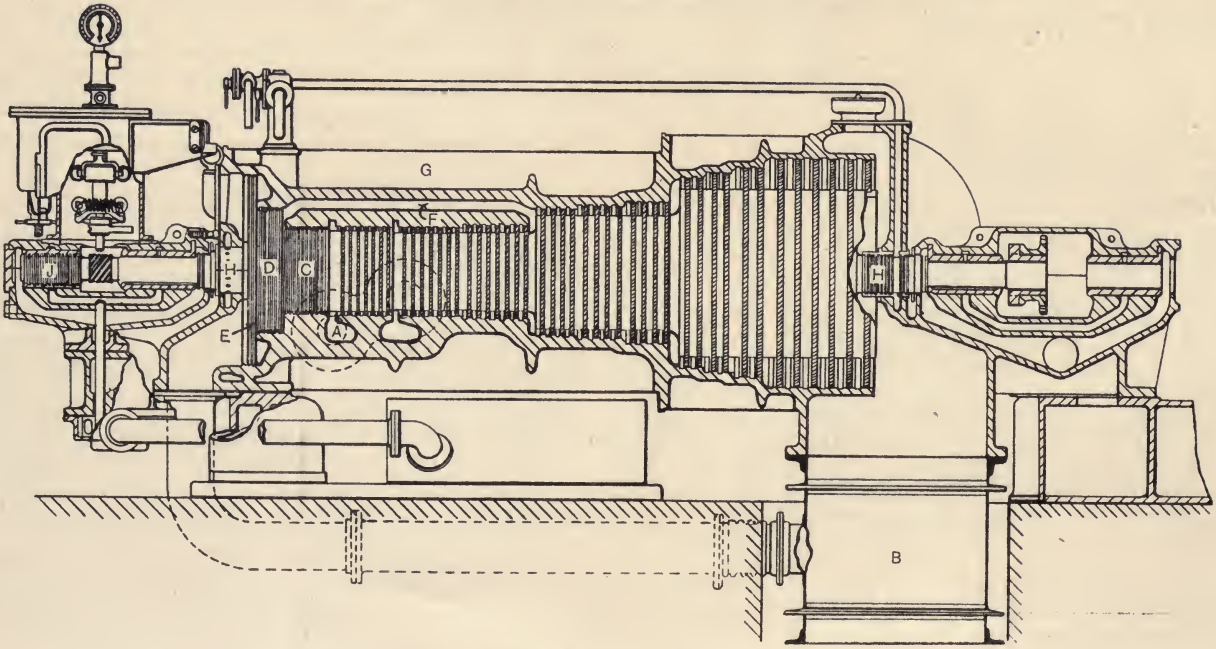
The action of the Air Pump is as follows:—Steam passes from the cylinder through the exhaust pipe into the top of the condenser, when it meets a jet of water from the injection valve, and is there condensed, falling to the bottom of the condenser. When the bucket has reached the back end of its stroke it has forced all the water and air out of the barrel through the delivery valves; it now returns and creates a vacuum in the barrel, and when it has passed over the diagonal holes, the water, vapour, air, &c., in the condenser at once rush into the barrel to be ejected on the backward stroke through the delivery valves into the hot well.

SUPPLIED BY

Messrs. POLLIT & WIGZELL, Ltd.,

Engineers, Sowerby Bridge.

— PARSON'S COMPOUND STEAM TURBINE. —



— SECTION THROUGH TURBINE. —

Supplied by Messrs. C. A. PARSONS & CO., Ltd., Heaton Works, NEWCASTLE-ON-TYNE.

PARSON'S COMPOUND STEAM TURBINE.

(See Opposite Page.)

The steam turbine which is shown in section on the opposite page consists of a cylindrical case with rows of inwardly projecting blades, within which revolves a concentric shaft with rows of outwardly projecting blades. The steam enters at A on the lower half of the cylinder, thus leaving the upper half quite clear of steam pipes and all obstructions, and facilitating dismantling. It then passes successively through the different rows of fixed and moving blades, and leaves the cylinder through the exhaust pipe B. In order to give increased passage way for the steam as it expands, the shaft is made with three steps of different diameter, the heights of the blades being also increased.

The steam, in addition to its rotational force, exerts a pressure endways along the shaft on the surface of the blades and the shoulder of the shaft. This is balanced by the dummy pistons, C, D and E, as shown in the section. They are made of diameters corresponding to the different parts of the turbine they balance, and are supplied with the corresponding steam pressure through the pipes F and G. The shaft thus runs in complete balance endways, and can be moved backwards and forwards with a light lever even when the turbine is running under full load.

In order to prevent steam leakage, grooves are turned in these pistons, into which project, without however, touching the moving parts, suitably shaped strips of brass caulked into grooves in the cylinder. The whole form a labyrinthian passage, offering great resistance to steam, most of which is carried round and round by the skin friction of the dummy pistons, producing a most effective screen against leakage.

The two glands H. H. where the shaft leaves the turbine casing, are constructed in precisely the same manner. The steam for packing them is obtained from the exhaust of the steam relay, a live steam connection being fitted for use before starting up. An ejector is also fitted to draw the excess steam away from the glands.

The coupling between turbine and generator is of the flexible class type, to allow for slight differences in alignment of the two portions of the plant. The thrust block J at the end of the turbine shaft merely keeps it in place with the right clearance between the fixed and moving parts of the glands and dummies, and adjustment is made in a few minutes with a small liner behind the thrust block. The shafts themselves are solid steel forgings in the smaller sizes, while in the larger sizes they are built up of hollow steel drums machined inside and outside, and then carefully shrunk together and pinned.

The blades are composed of a special brass alloy, which long experience has proved to be the most suitable. This is rolled and drawn to the required section, and highly polished so as to ensure the friction with the steam being as little as possible. For the first few rows of blades, copper is used instead of brass, as being more suitable for superheated steam. Turbines fitted with this blading have been opened up after running many years, and not the slightest cutting action has been visible on any of the blades.

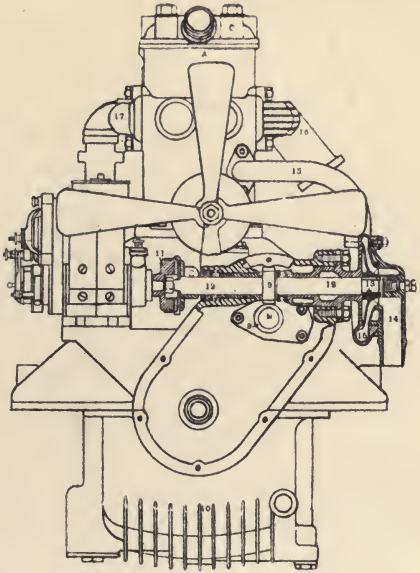
Supplied by

Messrs. C. A. PARSONS & CO., Limited.

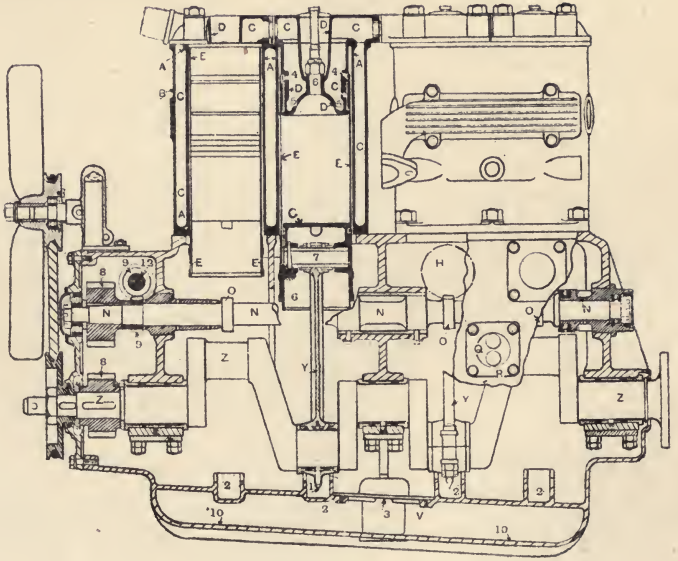
Heaton Works, NEWCASTLE-ON-TYNE.

THE ARGYLL 25 H.P. SINGLE SLEEVE VALVE ENGINE.

AS USED ON THE ARGYLL MOTOR CARS.



FRONT ELEVATION (Partly in Section).

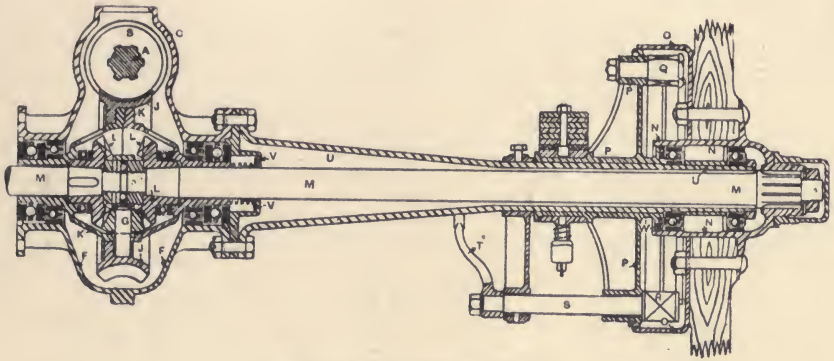


SIDE ELEVATION (Partly in Section).

A, cylinder.
B, water jacket.
C, water space.
D, cylinder head.
E, single sleeve valve.
G, piston.
H, sleeve valve actuating disc.
K, skew cut teeth on disc H.
L, detachable journal taking disc H.
N, valve gearshaft.
O, driving skew gear on gear shaft.
Q, oil pump.
R, oil pump cover.
V, oil sump.
Y, connecting rod.
Z, crankshaft.
1, oil dipper on connecting rod end.
2, oil trough.
3, oil filter plate.
4 and 5, gas rings in cylinder head.
6, sparking plug.
7, gudgeon pin.
8, distribution chain wheels.
9, skew gear wheels driving magneto and water pump.
10, under cover to crank chamber with radiating flanges.
11, dog connecting magneto spindle to drive.
12, magneto and water pump spindle.
13, water circulating pump.
14, water suction pipe.
15, water delivery pipe.
16, exhaust trunk,
17, inlet pipe.

Supplied by Messrs. ARGYLL'S, Limited, ALEXANDRIA, N.B.

DETAILS OF BACK AXLE.



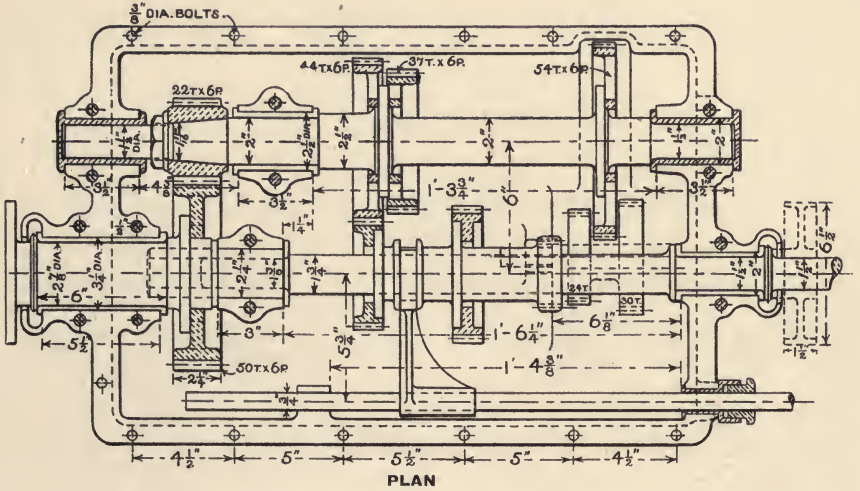
VERTICAL LONGITUDINAL SECTION.

A, propeller shaft.
B, worm.
C, socket on differential gear box taking rear end of torque tube.
D, ball bearings of worm.
E, ball thrust bearings of worm.
F, differential gear case.
G, planet wheels of differential gear.
H, oil filling orifice.
I, oil drain.
J, worm wheel.
K, differential gear box.
L, sun wheels of differential gear on end of driving shafts.
M, driving shafts.
N, driving wheel hub.
O, brake drum.
P, brake and spring table carrier.
Q, brake pivot.
R, brake expanding cam.
S, brake cam spindle.
T, brake cam lever.
U, live axle casing.
V, spring oil-retaining collar.
W, oil-retaining washer.

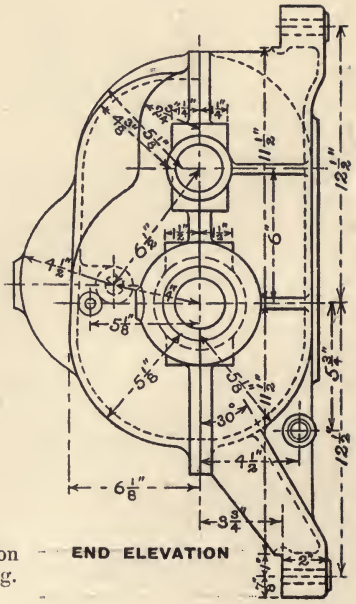
SINGLE SLEEVE VALVE ENGINE.

The drawings on the opposite page show the Argyll 25 H.P. Single Sleeve Valve Engine for Motor Cars. The cylinders A are cast in pairs, but have independent detachable heads D. The piston reciprocates within the single sleeve E, which sleeve has a vertical and partially rotating movement by means of the sleeve actuating disc H, which is skew gear driven from the gear shaft N. Three specially shaped exhaust ports and three inlet ports are formed in each cylinder; but each sleeve is made with five ports only, the central port being of double form and acting for both inlet and exhaust. The crankshaft Z is of 2⅛" dia. chrome nickel steel, and rotates in three white metal lined bearings. The pistons are of cast iron, 5" long. The gear shaft N is driven from the crankshaft by a Coventry Silent Chain.

— SPEED GEAR BOX FOR MOTOR OMNIBUS. —



PLAN



END ELEVATION

This view is a plan of the bottom half of gear box, showing the gears. The end elevation shows the gear box complete with the necessary lugs for bolting to the omnibus framing. This gear box can also be supplied with ball bearings.

Supplied by MESSRS. **DAVID BROWN & SONS (HFD.) LTD.**, Park Works, Lockwood, HUDDERSFIELD.

WEIGHT ESTIMATING.

To estimate the weight of any detail, multiply its volume in cubic inches (or cubic feet) by the weight of a cubic inch (or cubic foot) of the material.

(1) Bar or Plate of uniform square or rectangular section.

Volume = Length × Breadth × Thickness.

EXAMPLE :—Estimate the weight of a mild steel boiler plate, 10ft. long, 3ft. wide, 1in. thick, if 1 cubic foot of mild steel weighs 490 lbs.?

Weight = $10 \times 3 \times \frac{1}{12} \times 490 = 1{,}225$ lbs. ANS.

(2) Solid Bar or Shaft of uniform circular section.

Volume = Length × Area of Cross-section.

Area of cross-section = π $\left(\text{or } \frac{22}{7}\right)$ × radius^2, or ·785 × dia^2.

EXAMPLE :—Estimate the weight of a wrought iron bar 24″ long, 4″ diameter, if one cubic inch of wrought iron weighs ·28 lbs.

Weight = $24 \times \frac{22}{7} \times 2 \times 2 \times \cdot 28 = 84{\cdot}4$ lbs. ANS.

(3) Hollow Spindle of uniform circular section.

Volume = Length × Area of Cross-section.

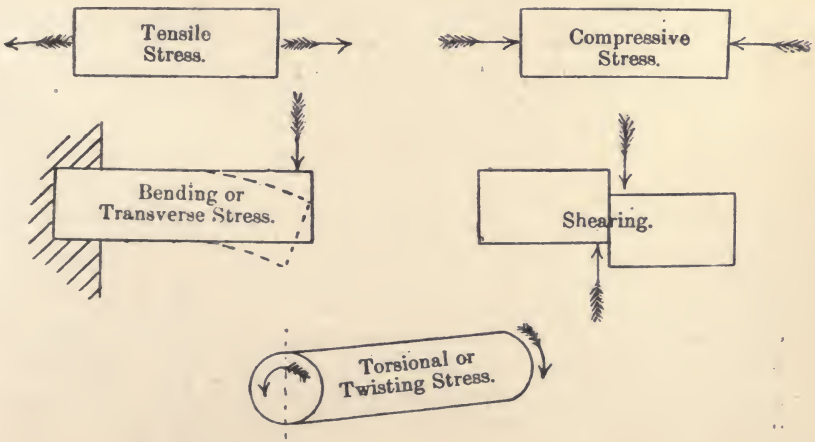
Area of Cross-section = Area of outer circle – Area of inner circle.

EXAMPLE :—Estimate the weight of a cast iron hollow spindle, 2′ 6″ long, outside diameter 6″, inside diameter 3″. The weight of a cubic inch of cast iron is ·26 lbs.

Weight = $30 \times (28{\cdot}27 - 7{\cdot}07) \times \cdot 26 = 165{\cdot}36$ lbs. ANS.

Give examples of some of the straining actions to which machines are subjected.

(323)



AVERAGE WEIGHTS AND STRENGTHS OF MATERIALS.

MATERIAL.	Weight of 1 Cubic foot.	Weight of 1 Cubic inch.	Tensile Strength.	Compressive Strength.	Shearing Strength.
	lbs.	lbs.	Tons per sq. in.	Tons per sq. in.	Tons per sq. in.
Cast Iron ...	450	·26	7·5	45	8
Wrought Iron	480	·28	21	21	17
Mild Steel ...	490	·29	28	23	21

— NOTES ON MATERIALS. —

CAST IRON

is crystalline, brittle, fluid at high temperatures, takes complicated shapes by casting in a mould It contains from 2 to 6 per cent. of carbon, is six times as strong in compression as in tension, separate parts are mostly connected by bolting. It may be toughened by having the carbon baked out, causing conversion into malleable cast-iron. Machine Beds and Frames are cast because of size and complexity. Columns or Pillars are cast on account of strength of cast iron in compression. Surface plates are cast on account of the crystalline nature allowing a better and more enduring surface to be obtained.

WROUGHT IRON

is fibrous, tough, soft, ductile at high temperatures, but not fluid, it is weldable at 1500° or 1600° Fahr., is easily oxidized ; may be forged, hammered or rolled to various shapes ; contains not more than 0·25 per cent. of carbon ; about equal strength in tension and compression ; may be case-hardened or surface-hardened, leaving the inside soft and tough. Motion-pins and Blocks are made of wrought iron for toughness, and case-hardened for surface wear. Bolts, Rivets, Tie-rods, etc., are wrought on account of tensile strength.

STEEL

is a compound of iron with a small quantity of carbon. It can be made by extracting carbon from cast iron (Bessemer and Siemens-Martin processes) or by adding carbon to wrought iron (cementation process). CAST STEEL, as used for cutting tools, has a tenacity of 50 to 60 tons per square inch. It is hard, brittle, and elongates very little before breaking. NICKEL STEEL contains about three per cent. of nickel. It is less liable to corrosion than ordinary steel and its tensile strength is 35 to 40 tons per square inch. Where high pressures have to be resisted steel castings are often used instead of cast iron. Shafts, Spindles, Steam Boiler Plates are usually made of mild steel.

NOTES ON MATERIALS.

COPPER.

Pure copper is very malleable and ductile. Its chief properties are (1) high conductivity, (2) high malleability, (3) resistance to corrosion. For (1) it is used in locomotive fireboxes, for (2) and (3) screwed stays and expansion pipes are made of copper. The tensile strength of cast copper is 8 to 12 tons per square inch, and for forged copper about 15 tons per square inch. 1 cubic foot of copper weighs 550 lbs. and 1 cubic inch, ·32 lbs.

BRASSES.

Ordinary brass is an alloy containing about two parts of copper to one part of zinc, and has a tenacity of about 12 tons per square inch. MUNTZ METAL contains three parts of copper to two parts of zinc, and has a tenacity of about 22 tons per square inch, it is used for ships fastenings, etc. NAVAL BRASS contains 62 parts of copper, 37 parts of zinc and 1 part of tin (tin hardens the alloy). DELTA METAL is a copper-zinc alloy with a small proportion of iron added. One cubic foot of brass weighs 525 lbs., and 1 cubic inch ·3 lbs.

BRONZES.

The best quality bronze or gun-metal, suitable for ordinary bearings, consits of 9 parts of copper to 1 part tin, and has a tenacity of 17 tons per square inch. 92 parts copper to 8 parts tin gives a soft tough bronze suitable for gear wheels. The Admiralty specification for gun-metal is 88 parts copper, 10 parts tin, and 2 parts zinc. PHOSPHOR BRONZE is an alloy of ordinary bronze with a small quantity of phosphorus added, and has a tenacity ranging from 20 tons per square inch in the softer varieties to 50 or 60 tons when in the form of wire. It is used for propellers, pump rods, etc. MANGANESE BRONZE is an alloy of ordinary bronze and ferro-manganese. It can be forged or rolled and is equal in strength to mild steel. Manganese bronze resists the corroding action of sea water, and is thus specially suited for screw propeller blades. ALUMINIUM BRONZE containing 90 parts of copper and 10 parts of aluminium has a tensile strength of 50 tons per square inch, and is used for motor car axles. The weight of 1 cubic foot of ordinary bronze is 540 lbs., and 1 cubic inch ·31 lbs.

WHITE METAL.

White Metal or Babbitt's Metal is used for lining bearings. The usual composition is 96 parts of tin, 4 parts of copper and 8 parts of antimony. The weight of 1 cubic foot is 456 lbs., and 1 cubic inch ·26 lbs.

MISCELLANEOUS.

The ultimate tenacity of leather belting varies from 3000 to 5000 lbs. per square inch. The working stress should not exceed 300 to 350 lbs. per square inch, *i.e.* a Factor of Safety of 10 to 12 is adopted. The ultimate tenacity of cotton driving ropes is about 8000 lbs. per square inch, the working stress should not exceed 280 lbs. per square inch.

MATERIAL.	1 Cubic foot weighs lbs.	1 Cubic inch weighs lbs.	MATERIAL.	1 Cubic foot weighs lbs.	1 Cubic inch weighs lbs.
Aluminium ...	160	·093	Zinc	437	·25
Lead...	710	·41	Fresh Water ...	62·5	·036
Tin	460	·27	English Oak ...	54	·031

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INDEX.

	Page.
Adamson's Rings	14
Adjustable Footstep Bearing...	34
,, Joint for Rods ...	110
Air Compressor	112
,, ,, Piston for ...	72
Air Pump and Bucket	113
Angle Iron and Joint ...	14, 15
Argyll Single Sleeve Valve Engine	116, 117
Axle Box, Locomotive	38
Axle, Rear for Motor Car ...	117
Balance Weight for Oil Engine	72
Ball Valve...	74
,, Bearings	36
Bearings ... ... 31 to 38,	65, 105
,, Ball	36
,, Crank Shaft	35
,, Electric Motor	105
,, Oil Bath...	37
,, Pressure on	65
,, Ring Oiled 37, 88, 99,	102, 105
,, Roller	37, 38
,, Swivelling	37, 40
Bell Crank Lever	9
Belt Pulleys	39, 40
Bevel Wheels	44
Blocks, Slide	9, 65, 69
Boiler Plates, Joints for ...	10 to 16
Boiler, Cochran's Vertical ...	106
,, Lancashire	107
,, Manhole...	108
,, Marine	108
,, Stays	108
Bolts, Coupling	28, 54
,, Foundation	18
,, Method of Breaking ...	19
,, and Nuts, proportions of	17, 19
,, Various kinds of	17
Bowling Hoop	14
Box Key	18
Bracket for Lathe	8
,, Hanging	32
,, Pillar	33
,, Wall	33
Branch and Elbow Pipe	8
Brasses for Bearings...	31
Bridge Work, Joints for plates in	12
Brush Rocker	101
Bucket, Air Pump	113
Built-up Wheels...	45
Cams, The Design of ...	85, 86
Carrier for Lathe	93
Caulking and Fullering	13
Chain Wheel and Chain	85
Channel Iron	14
Chuck, Four Jaw	92
Claw Clutches	29
Clutches, Friction	29, 30
Cocks, Bib and Drain	75

	Page.
Combined Lap and Butt Joint	12
Compressor, Air...	112
Condenser	113
Cone, Three Speed	40
Cone Keys	23
Conical Clutch	29
Connecting Rods ... ... 58 to	64
Connection of Parallel Plates...	16
Corliss Engine Cylinder	50
Cotters... ... 23, 24, 58, 62,	63, 69
Cottered Joints, Proportions for	24
Countershaft, Lathe	40
Coupling Bolts	28, 54
Couplings for Propeller Shaft...	28
,, ,, Shafting ... 27 to	30
Cranks	52, 53
Crank Axle, L. & N. W. Ry....	55
Crank-Shaft Bearing	35
,, for Locomotive	53, 55
,, S.S. "Majestic" and "Teutonic"	54
Crank-Shaft for Motor Car ...	41
Crossheads ... ... 23, 65, 68 to	70
Cunard, S.S. Details... 28, 78,	79
Cycloidal Teeth	46
Cylinder Cover and Stuffing Box	48
Cylinders ... ... 47 to	50
,, Corliss Engine	50
,, for Vertical Engine...	49
,, Escape Valves	79
Diagrammatic Sketch of Steam Engine	47
Differential Gears	117
Dimensioning Drawings	4
Disc Crank	53
Double Ported Slide Valve ...	75
Double Ram Pump	111
Drawing to Scale, Notes on, etc. 2 to	7
Drill Gear Box	95
Driving Headstock for Lathe 87 to	89
Driving Plate for Lathe	93
D Slide Valve 47,	74
Eccentrics 56,	57
Electrical Details ... ...99 to	105
Electric Motors ... 99, 102 to	104
Escape Valve for Cylinder ...	79
Expansion Valve, Meyer's ...	75
Explosion Valve	77
Faceplate	93
Fast-Headstock for Lathe 87 to	89
Fast and Loose Pulleys ... 39,	40
Feather Keys	22
Field Magnets	100
Flange Coupling for Shafts ...	28
Flanged Joint	26
Flap Valve	74
Fly-Wheel for Motor Car ...	41
Footstep Bearing	34
Foundation Bolts	18

	Page.
Four Jaw Chuck	92
Friction Clutches	29, 30
Fullering	13
Galloway's Tubes	15
Gas Engine Details	64
Gear Box for Radial Drill ...	95
Gear Box for Motor Omnibus...	118
Gearing, Toothed	43 to 46
General Instructions...	1
Gib and Cotter	23, 58, 63
Girder, Wrought Iron Plate ...	16
Glands and Stuffing Boxes	47 to 51
G. N. Ry. Connecting Rod ...	62
Governors, Hartnell	71
Gusset Stay	15
G. W. Ry. Eccentric	56
Hanging Bracket	32
Hartnell Governors	71
Headstocks, Lathe	87 to 90
Hollow Crank-shaft	54
Horizontal Engine Cylinder ...	47
How to Draw Rivet Heads ...	10
Hydraulic Piston	110
Injector	109
Inking in and Colouring	6
India Rubber Disc Valve... ...	74
Invert Wheel	85
Involute teeth	46
Joints, Cottered...	24
,, Knuckle	24
,, for Pipes	25, 26
,, for Rods (adjustable)...	110
Journals for Shafts	27, 65
Keys, Holroyd Smith's Method	22
,, Proportions of... ...	21 to 23
Keys, Various kinds of	21 to 23, 55
Knuckle Joint	24
Lancashire Boiler	107
Lathe, Carrier	93
,, Chuck	92
,, Countershaft...	40
,, Faceplate	93
,, Headstocks ...	87 to 90, 96
,, Slide Rest	98
,, Stay	91
Leaded Socket Joints for Pipes	26
Lever, Bell Crank	9
Link Plate	7
L. & N. W. Ry. Crank Axle...	55
,, ,, Connecting Rod End	63
Lock-nuts	19
Locomotive Axle Box	38
Locomotive Crank Shafts	53, 55
Loose Headstocks	90. 96
Lozenge Joint for Plates	12
Lubricators	73
L. & Y. Ry. Piston	66
Machine Vice	96
Magnets, Field	100
Manhole	108
Marine Boiler	108
Marine Engine, Connecting Rod	60
,, ,, Crank Shaft ...	54
,, , Thrust Block...	36
Materials, Notes on ...	120, 121
Metallic Packing	51
Meyer's Expansion Valve ...	75
Midland Ry. Valves... ...	82, 83
Motor Car Details ...	36, 41, 117
,, ,, Engines 116,	117
,, Electric ...	99, 102 to 104
,, ,, Details	100, 101, 105
,, Omnibus Speed Gear Box	118
N. E. Ry. Regulator Valve	80, 81
Notes on Materials	120, 121
Nuts for Bolts	17 to 19
Oil Bath Bearings	37
,, Engine Balance Weights ...	72
Packing, Metallic	51
,, for Pump Rods ...	110
Parallel Plates, Connection of	16
Parkinson's Vise	97
Parson's Steam Turbine ...114,	115
Pedestals	31
Petrol Engines 116,	117
Photo Printing and Tracing ...	5
Pillar Bracket	33
Pinion Wheel	85
Pipes and Pipe Joints ...	25, 26
Piston and Connecting Rod for Gas Engine	64
Piston, for Air Compressor ...	72
,, L. & Y. Ry.	66
,, Hydraulic	110
,, Rods ... 23, 47 to 51,	66, 69
,, Steam Engine	67
,, Valves	49
Plate Girder	16
Plummer Blocks	31
Principles of Projection	2
Propeller Shaft Coupling from the R.M.S. "Lusitania" ...	28
Proportions of Bolts and Nuts	17, 19
,, ,, Joints for Rods...	24
,, ,, Keys	21, 22
,, ,, Knuckle Joint...	24
Proportions for Pedestals... ...	31
,, ,,Pipes(Hydraulic)	25,26
,, ,, Riveted Joints	10, 11
,, of Shaft Journal ...	27
,, for Toothed Gearing	43
Pulleys, Belt	39, 40
,, Fast and Loose ...	39, 40

(Continued on Page 126.)

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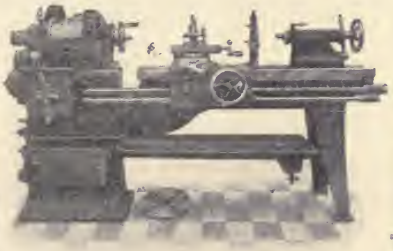

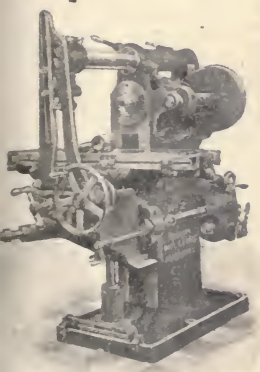

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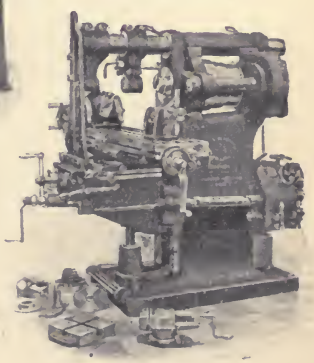

MACHINE TOOLS.

Page.

Pulleys, Rope 42
Pump Double Ram 111
,, Rod Packing, S. E. A. Rings, for the R. M. S. "Olympic" 110

Rack and Pinion 85
Ratchet Wheel 85
Regulator Valve, N. E. Ry. 80, 81
Ring Oiled Bearings 37,88,99,102,105
Riveted Joints ... ... 10 to 16
Rivets, Forms of 10
,, Method of Drawing ... 10
R.M.S. "Lusitania" Details... 28
R.M.S. "Olympic" Details ... 110
Rocker, Brush 101
Rods, Adjustable joint for ... 110
,, Joints for 24
Rope Pulleys 42
Roller Bearings 37, 38
Rules for Speed of Wheels and Pulleys 39, 44

Safety Valves, Midland Ry. 82, 83
,, ,, Triple 78
Scales, Notes on... ... ...3, 7
Screws, Forms of 17
Screw Threads 20
Sections, Use of... 3
Shaft Couplings 27, 28
Shafting 27
Shaft, Neck or Journal 27
Shaping Machine Tool Box ... 94
Shearing of Rivets 12, 13
Sight Feed Lubricator 73
Slide Bars 65
,, Blocks... ... ...9, 65, 69
,, Rest for Lathe 98
,, Valves 47, 74, 75
Socket Joint for Pipes 26
Spanners 18
Speed Calculation for Shafting 44
,, Gear Box 95, 118
Spur Wheel Teeth, Method of Drawing 46
Square Thread, How to Draw... 20
S.S. "Campania" Details 78, 79
S.S. "Majestic" Details... ... 54
Staking-on 23
Stationary Stay for Lathe ... 91
Stays, Boiler 108
Steam Engine Parts 47
Steam Turbine 114, 115
Steel Pipes, Connection for ... 26
Stop Valves 76, 77
Stresses and Strains 119
Strength of Materials 120
Stud 17
Stuffing Boxes ... ... 47 to 51
Swivelling Bearings 37, 40

Tearing of Boiler Plates 12

Page.

Tee, Iron Joint 16
Thrust Bearing 34
,, Block (Marine) 36
Tool Box, Shaping Machine ... 94
Tools for Caulking, etc. 13
,, ,, Lathe, Drills, etc. ... 84
Toothed Gearing ... ... 43 to 46
Tracing and Photo Printing ... 5
,, Examples 42
Triple Safety Valves 78
Turbine, Steam 114, 115
Two Speed Countershaft 40

Union Joints for Pipes 25
Universal Coupling 29
Use of Angle Iron . ... 14 to 16

Valve Box 47, 49
Valves, Ball 74
,, Cylinder Escape 79
,, Double Ported 75
,, D. Slide 47, 74
,, Explosion 77
,, Flap 74
,, India Rubber Disc ... 74
,, Piston 49
,, Regulator, N. E. Ry. 80, 81
,, Rods, Proportions of ... 24
,, Spring Loaded Safety 78, 79, 82, 83
,, Stop 76, 77
,, Triple Safety 78
,, Wing 74
Vertical Boiler 106
,, Engine Cylinder ... 49
,, Shaft, Bearings for ... 34
Vice, Machine 96
Vicker's Electric Motor 99
Vise, Parkinson's 97

Wall Box 32
,, Bracket 33
Washers, Proportions of 17
Water Pipes, Connections for... 26
Wedges for Adjusting Bearing Brasses 34, 35
Weight Estimating 119
Wheels, Bevel 44
,, Built-up 45
,, Chain.. 85
,, Helical 45
,, Mortice... ... ... — 44
,, Ratchet 85
,, Spiral 45
,, Spur ... ... 43 to 46
White Star S.S., Details... 54, 110
Wing Valves 74
Woodruff Key 23
Workshop Processes 84
Worm and Wheel 45, 85
Worm Thread Proportions ... 45
Wrought Iron Pipe Connections 26
,, ,, Pulleys 39

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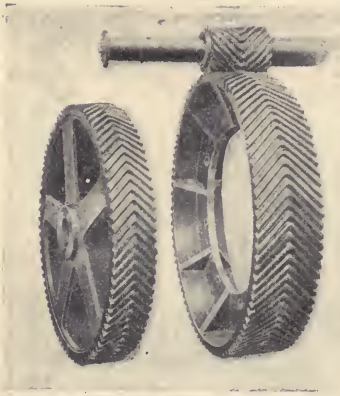

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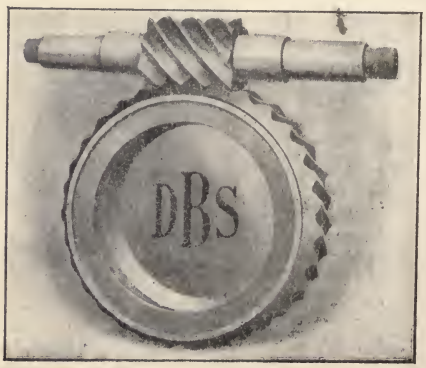

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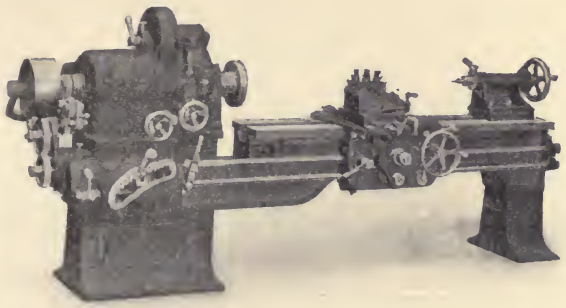

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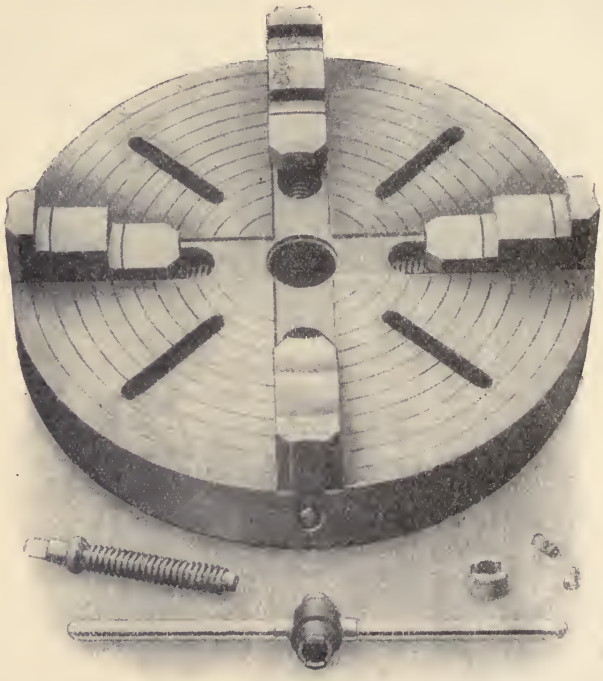

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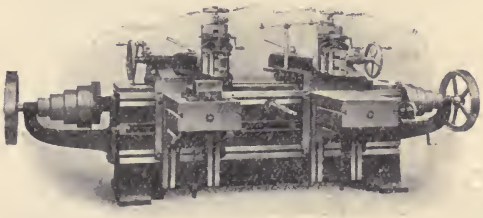

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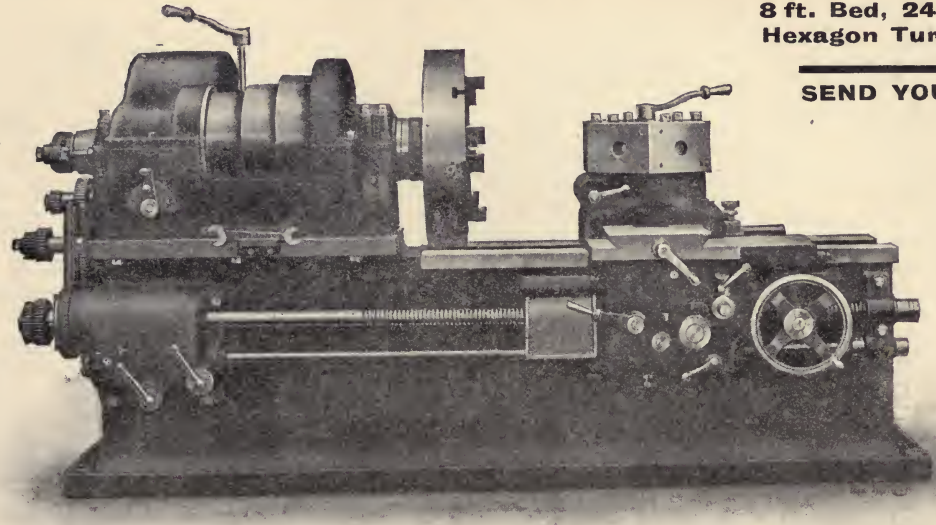

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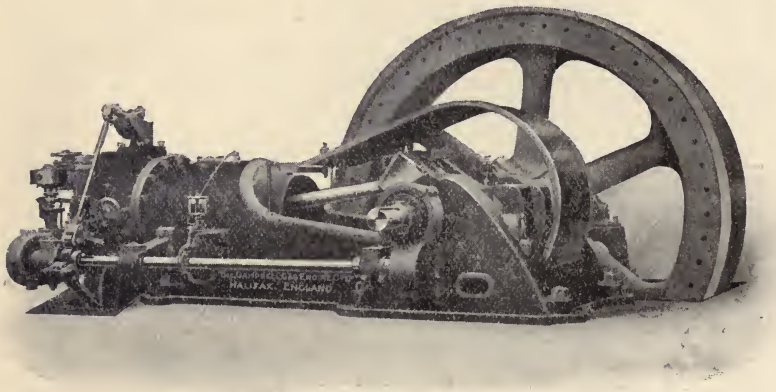

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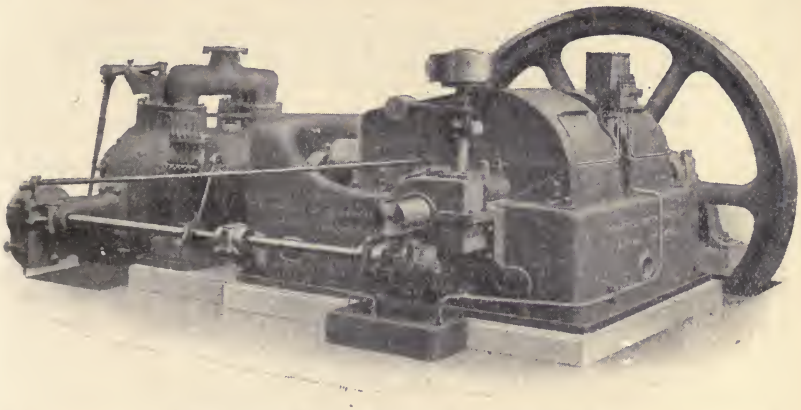

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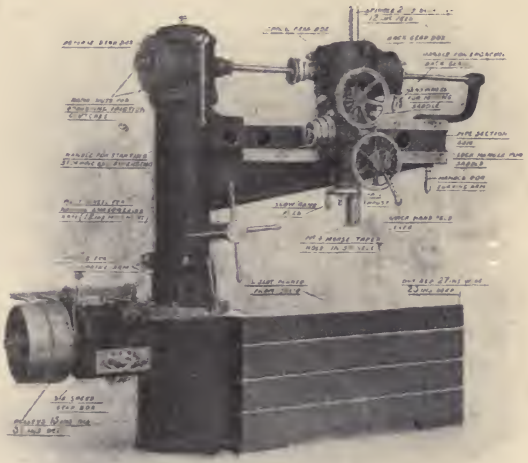

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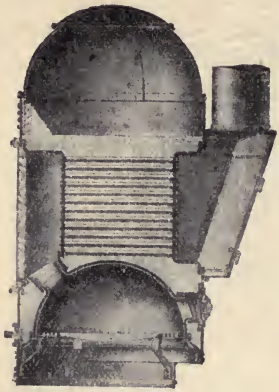

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4	0	9	0	120	92	12	0	15	16	0
4	3	9	6	140	105	5	0	17	18	0
4	6	10	0	160	117	18	0	17	18	0
4	9	10	3	200	127	7	0	18	19	0
5	0	11	3	220	138	19	0	20	3	0
5	3	11	9	250	150	10	0	20	3	0
5	6	12	3	300	164	4	0	20	3	0
5	9	13	0	350	178	18	0	20	14	0
6	0	12	6	350	189	9	0	22	6	0
6	0	13	6	350	189	9	0	22	6	0
6	0	14	0	400	197	17	0	22	6	0
6	6	13	6	450	209	9	0	23	9	0
6	6	14	0	450	209	9	0	23	9	0
6	6	14	6	500	215	15	0	23	9	0
7	0	14	0	500	233	13	0	25	6	0
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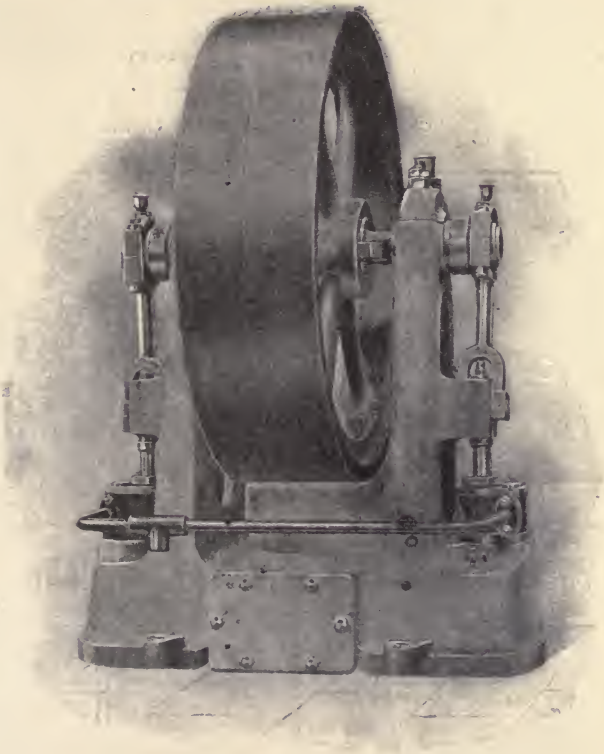

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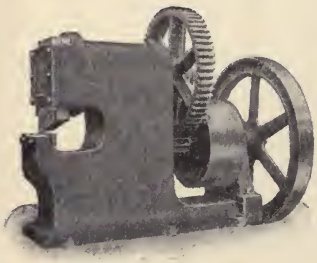

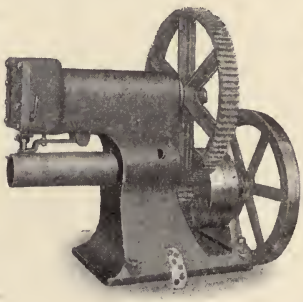

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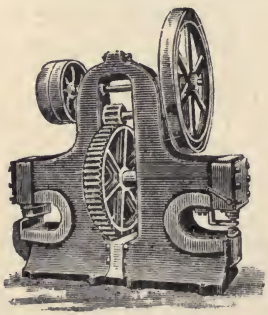

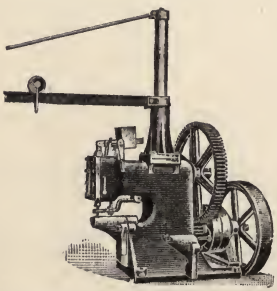

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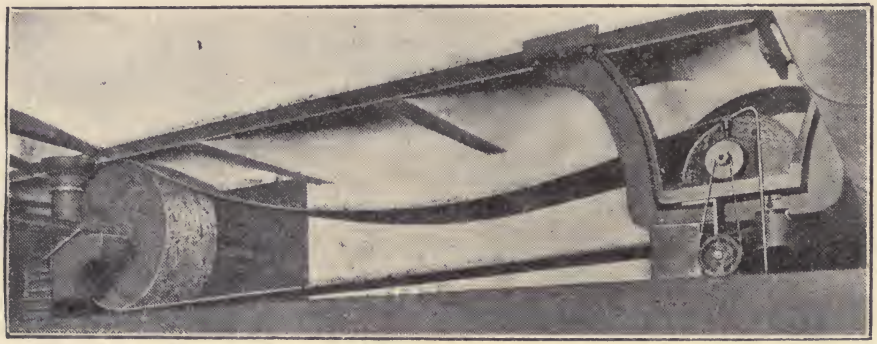

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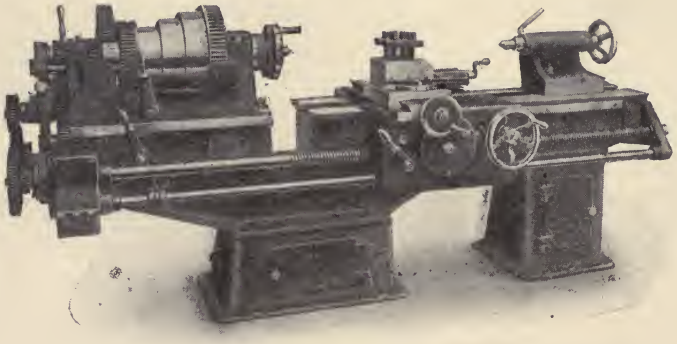

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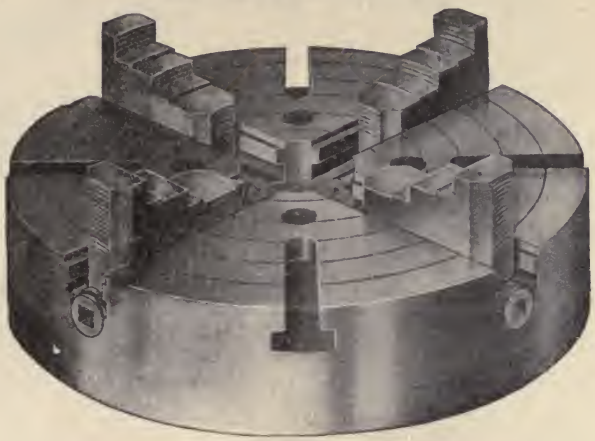

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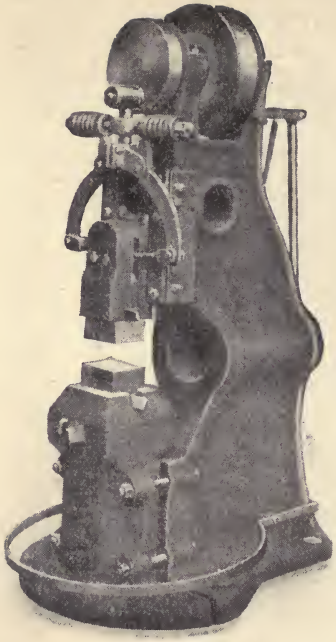

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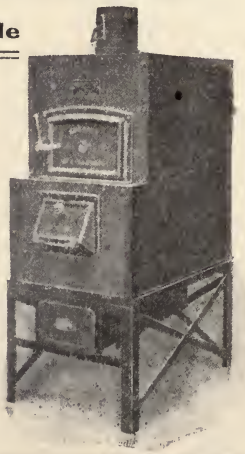

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Index to Advertisers.

August's Muffle Furnaces, Ltd.	144
Bentley Publishing Co., The	122
Berry, Henry & Co., Ltd.	139
Broadbent, Henry, Ltd.	129
Brown, David & Sons, (Hfd.) Ltd.	128
Campbell Gas Engine Co., Ltd., The	134
Do. Do. Do.	135
Cochran & Co., Annan, Ltd.	138
Fleming, Birkby & Goodall, Ltd.	127
Hamer, S. H.	130
Holmes, Henry & Co.	131
Maud & Turner, Ltd.	138
"Mechanical World," The	145
Mitchell, D. & Co., Ltd.	137
Parkinson, J. & Son	125
Patent Cork Pulley Co., Ltd.	141
Pratt, F. & Co., Ltd.	143
Scott Bros. (Halifax), Ltd.	140
Spencer, John & Co. (Keighley), Ltd.	144
Stanley Machine Tool Co., Ltd., The	142
Swift, George & Sons, Ltd.	132
Tasker & Crossley	133
Thornton, A. G., Ltd.	143
United States Metallic Packing Co., Ltd., The ...	136
Whitehead, A. & Co.	133

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